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Elisha Mitchell Scientific Society

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CHAPEL HILL, N. C., U. S. A.

The Elisha Mitchell Scientific Society

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JOURNAL

OF THE

Elisha Mitchell Scientific Society

Volume 53 December, 1937 No. 2

PROCEEDINGS OF THE THIRTY-SIXTH ANNUAL MEETING OF THE NORTH CAROLINA ACADEMY OF SCIENCE

CATAWBA COLLEGE, SALISBURY, N. C., MAY 7 AND 8, 1937

The thirty-sixth annual meeting of the North Carolina Academy of Science was held at Catawba College, May 7 and 8, 1937. The meeting was called to order at 9:30 A.M. on May 7 by the President, P. M. Ginnings. The reading of papers commenced promptly and continued until 11:30 A.M. when the President announced the appointment of the following committees:

Auditing: J. B. Derieux, G. H. Satterfield, A. F. Thiel;

Resolutions: J. P. Givler, R. J. Campbell, E. E. Randolph;

Nominating: H. B. Arbuckle, J. S. Holmes, F. A. Wolf.

The reading of papers was continued until 1:30 P.M. when the Academy took a recess for luncheon.

The reading of papers was resumed at 2:15 and continued until 4:00 when the Academy held its annual business meeting.

The minutes of the previous meeting were approved as published in the JOURNAL OF THE ELISHA MITCHELL SCIENTIFIC SOCIETY.

Reports from the various committees were presented.

The executive committee, consisting of P. M. Ginnings, president of the Academy; C. F. Korstian, vice-president; H. L. Blomquist, secretary-treasurer; W. E. Speas, H. R. Totten, and W. L. Porter, reported as follows:

"The executive committee met in Salisbury on May 6 and on May 7 with all members present.

"The committee appointed W. L. Porter to act as temporary assistant to the secretary during the meeting.

"One title which had been accidentally omitted was added to the program.

"One title which arrived too late to go on the printed program was added to the program.

"Extension of time up to 30 minutes was granted to Frank K. Cameron for his paper 'The Utilization of Whole Cotton'.

"The request by G. R. McCarthy and J. W. Huddle that their paper be read in their absence by Grover Murray was granted.

"The secretary was instructed to see that in all the sections, except the chemistry section, no officer be elected who is not a member of the Academy in good standing. The committee expressed the desirability that the secretary of the chemistry section be a member of the Academy so that he may receive the announcements and the program of the Academy.

"The committee reported as elected to membership since the last meeting the following:

Dr. J. E. Adams, Dept. of Botany, U. N. C., Chapel Hill, N. C.
Mr. Bill Arey, 102 South Church St., Salisbury, N. C.
Mr. Walter Lane Barksdale, Dept. of Botany, U. N. C., Chapel Hill, N. C.
Dr. E. Willard Berry, Dept. of Geology, Duke University, Durham, N. C.
Dr. Robert B. Burrows, Box 221, Elon College, N. C.
Mr. George A. Christenberry, Dept. of Botany, U. N. C., Chapel Hill, N. C.
Mr. J. M. Clarkson, N. C. State College, Raleigh, N. C.
Miss Roxie Collie, N. C. State Museum, Raleigh, N. C.
Mr. Franklin Crowell, 512 E. Bank St., Salisbury, N. C.
Miss Sarah Culbreth, Dept. of Zoology, Duke Univ., Durham, N. C.
Mr. Joel E. Derrick, Spencer, N. C.
Mr. Richard A. Faust, 406 Mitchell Ave., Salisbury, N. C.
Mr. James Ferger, Dept. of Botany, N. C. State College, Raleigh, N. C.
Mr. Charles H. Flory, Box 1724, High Point, N. C.
Miss Frances K. Foust, U. N. C., Chapel Hill, N. C.
Mr. Kenneth H. Garren, Dept. of Botany, Duke Univ., Durham, N. C.
Mr. F. P. Gaskins, Phipps & Bird, Inc., 915 E. Cary Street, Richmond, Va.
Dr. John J. Gergen, Box 4771, Duke University, Durham, N. C.
Mr. Leland J. Gier, Campbell College, Buies Creek, N. C.
Mr. William Lanier Hunt, Box 169, Chapel Hill, N. C.
Dr. Thomas Kerr, Box 5035, N. C. State College, Raleigh, N. C.
Mr. F. J. le Clair, U. S. Soil Conservation Service, Chapel Hill, N. C.
Miss Jean Leitner, Dept. of Botany, U. N. C., Chapel Hill, N. C.
Dr. F. H. McCutcheon, Dept. of Zoology, N. C. State College, Raleigh, N. C.

Mr. Berlen C. Moneymaker, Box 134, Murphy, N. C.
Mr. Grover Murray, Jr., Dept. of Geology, U. N. C., Chapel Hill, N. C.
Dr. John M. Parker, III, Box 5171, N. C. State College, Raleigh, N. C.
Mr. Avery Patton, Jr., Davidson College, Davidson, N. C.
Mr. John H. Pierczynski, Bureau of Identification, Police Dept., Charlotte, N. C.
Miss Caroline E. Powell, Boyden High School, Salisbury, N. C.
Mr. F. P. Pratt, Jr., 528 Mitchell Ave., Salisbury, N. C.
Mr. Donald D. Ritchie, Dept. of Botany, U. N. C., Chapel Hill, N. C.
Miss Laurie M. Stewart, Dept. of Botany, U. N. C., Chapel Hill, N. C.
Mr. H. W. Straley, III, Dept. of Geology, U. N. C., Chapel Hill, N. C.
Dr. Herbert C. Tidwell, Wake Forest Medical School, Wake Forest, N. C.
Mr. Henry Wagner, Catawba College, Salisbury, N. C.
Mr. Woodrow Wilson, Dept. of Zoology, Duke University, Durham, N. C.
Mr. W. F. Whitt, 521 Maupin Avenue, Salisbury, N. C.

"The following were reinstated to membership:

Dr. Lewis E. Anderson, Dept. of Botany, Duke Univ., Durham, N. C.
Mr. Clifford Beck, Boyden High School, Salisbury, N. C.
Dr. Sherwood Githens, Jr., Wake Forest College, Wake Forest, N. C.
Mr. M. A. Hill, U. N. C., Chapel Hill, N. C.
Dr. Z. P. Metcalf, N. C. State College, Raleigh, N. C.
Dr. Arthur E. Ruark, U. N. C., Chapel Hill, N. C.
Mr. S. O. Trentham, Mars Hill, N. C.

"The committee also reported the following losses during the year:

Lost by death: Dr. David H. Howard, Jr.
Lost by resignation: Mrs. Margaret Stoughton Abell
Dropped from the roll because of non-payment of dues: forty former members.

The Treasurer's report was as follows:

Financial Statement of the N. C. A. S. May 6, 1937

Receipts

Balance on hand April 23, 1936:		
Savings Account	$437.94	
Checking Account	132.06	
Cash on hand	4.00	
Total balance	$574.00	$574.00

Dues:			
1936	164.00		
1937	218.00		
Initiation fees:			
1936	26.00		
1937	50.00		
	$458.00	$458.00	
Replacement of returned checks		4.00	
Interest on savings		10.71	
Total receipts (Includes $50.00 transferred from savings to checking account)		$1,046.71	$1,046.71
Disbursements			
Stationery and printing	$62.02		
Programs, 1937	28.50		
Postage	2.36		
Returned checks due to insufficient funds	4.00		
Refund dues	2.00		
Books for H. S. Essay Prize	16.34		
Expenses for delivering prize	6.50		
Journal of E. M. S. S., 1936 ($250.00 from checking and $50.00 from savings)	300.00		
Charges on bank balance	1.00		
Clerical assistance	59.00		
Sec.-Treas. commission	45.00		
Refund Sec. dues	2.00		
Telegrams	.64		
Telephone calls	.40		
Receipt books	1.03		
Letter file	.67		
Stencils	1.87		
Interval timer	5.32		
Total disbursements	$538.65		$538.65
Total balance May 6, 1937			$508.06
Savings Account			
April 23, 1936	$437.94		
Interest	10.71		
	$448.65		
Withdrawn Dec. 8, 1936 ($50 transferred to checking; $50 cash to Journal)	$100.00		
Balance May 6, 1937	$348.65		$348.65
			$159.41
Dues on hand			8.00
Balance in checking account May 6, 1937			$151.41

The above report was made as of May 6, 1937.
Submitted by H. L. Blomquist, Secretary-Treasurer.
Audited May 7, 1937 by
J. B. Derieux,
G. Howard Satterfield,
A. F. Thiel.

"The committee accepted the invitation of the Faculty of the North Carolina State College of the University of North Carolina to hold the thirty-seventh annual meeting of the Academy in Raleigh.

"The executive committee made the following recommendations to the Academy:

1. That all bills presented in the treasurer's report be authorized and paid and that the report be printed when audited.

2. That Bert Cunningham be appointed to select the books to be presented to the winner of the High School Science Essay Prize, and that he be authorized to draw upon the treasury as much as $25.00 for these books; and that the secretary be authorized to appoint a representative of the Academy to award the prize and draw upon the treasury for the payment of his expenses.

3. That hereafter the total expenditure for the High School Science Essay Contest be limited to $25.00.

4. That the Secretary-Treasurer be authorized to pay the Elisha Mitchell Scientific Society $300.00 for the publication of the 1937 Proceedings.

5. That C. W. Edwards of the Department of Physics, Duke University, and A. S. Wheeler, formerly acting chairman of the Department of Chemistry, the University of North Carolina, be made life members. Professor Edwards joined the Academy in 1902, was its president in 1903, and has been an enthusiastic and active member up to the present time. Dr. Wheeler joined the Academy in 1903, was its president in 1916, and has been an active member until last year when, because of ill health, he was compelled to retire from active duties."

The report and the recommendations of the executive committee were accepted and approved.

The auditing committee reported that the treasurer's report had been examined and was found to be correct.

The reports of the treasurer and auditing committee were accepted.

The committee on the Phipps and Bird Prize, consisting of Wm. F. Prouty, chairman, J. B. Derieux, J. P. Givler, Anne Pegram, O. J. Thies, and F. A. Wolf, reported as follows:

"The gold medal for the most noteworthy paper presented at the 1936 meeting was awarded to Dr. F. G. Hall, Duke University, for his paper, entitled 'Physiological Studies at High Altitudes.' The paper was awarded second place in the interstate academy contest."

The committee on high school science, consisting of Bert Cunningham, chairman, H. B. Arbuckle, Mrs. B. W. Wells, C. E. Preston, R. J. Campbell, and Mary Conrad Cleaver, reported as follows:

"Your Committee reports that it has carried on its usual activities during the year, including the Essay Contest.

There were 21 essays from 15 schools entered in the contest. The Judges, Dr. H. J. Oosting, Mrs. B. W. Wells, and Dr. C. E. Preston selected Miss Lucy Nelms of the Nashville High School as the winner of the prize. As in years passed this essay will be submitted to the High School Journal for publication. The Committee recommends that it be empowered to select the books for the prize (not to exceed $20.00) and that the Secretary of the Academy appoint a representative of the Academy to personally present the award at the Commencement Exercises of the Nashville High School.

The Committee has carefully considered the continuation of this prize, and has reached the following decisions:

(1) The prize should be continued. The number of essays submitted in any one year is no evidence of the extent of the influence of the contest. New schools are constantly submitting essays, and most schools do not enter the contest in consecutive years. Many essays are prepared which never come to the Academy since each school is limited to three entrants. We recommend that the prize be awarded next year in the fields of Chemistry and Physics.

(2) The Committee, however, feels that the present procedure of widely circularizing the schools does not bring commensurate returns. It suggests that the procedure for next year be altered by substituting personal correspondence with comparatively few teachers for the present system of broadcasting. This could probably be done at no expense to the Academy other than the prize itself, which the Committee feels should not be lessened. We recommend that this procedure be followed.

The Committee has also considered the possibility of creating an interest in the Academy on the part of the high school teachers. It suggests that this might be partly accomplished by having a special section with its own program on Saturday morning for this group. It also thinks it might be possible to create greater interest on the part of

teachers if the sponsor of the winner of the Essay Contest were given some recognition such as honorary membership in the Academy for a year. The Committee, however, is not ready to make specific recommendations on either of these latter matters."

The report of the high school science committee was accepted and its recommendations approved.

The legislative committee, consisting of Z. P. Metcalf, chairman, W. L. Poteat, and Wm. F. Prouty, had no report at this time.

The elective appraisal committee, consisting of P. M. Ginnings, chairman, E. H. Hall, R. E. Coker, Mary Conrad Cleaver, C. W. Edwards, Karl Fussler, E. G. Purdom, R. N. Wilson, J. T. Dobbins, reported that the committee had had no requests for appraisal and, therefore, had no report to make.

The conservation committee, consisting of Charles E. Raynal, chairman, B. W. Wells, J. P. Givler, C. F. Korstian, W. C. Coker, and J. S. Holmes, made the following report which was prepared and read by J. S. Holmes at the request of the chairman of the committee:

REPORT OF THE CONSERVATION COMMITTEE OF THE NORTH CAROLINA ACADEMY OF SCIENCE

By Dr. J. S. Holmes

The idea of conservation has undergone very considerable change since it was first linked with the better management of our natural resources some thirty years ago.

At the American Forestry Congress held in Washington, January 1905*, called by President Theodore Roosevelt "to establish a broader understanding of the forest in its relation to the great industries depending upon it; to advance the conservative use of forest resources for both the present and future need of these industries; to stimulate and unite all efforts to perpetuate the forest as a permanent resource of the nation," the word "conservation" does not seem to have been uttered, though foresters and lumbermen alike very fully discussed "conservative lumbering." By 1908, however, popular interest in forest conservation had become so keen that the same President "called together in conference the governors of all the States with their advisers, together with the presidents of the various national societies interested, and others, to discuss the broad question of the conservation of natural

* See Proceedings.

resources. As a consequence national and state conservation commissions were formed in all parts of the Union, and a new era of active interest in economic development seemed to have arrived,"* by the following year, 1909. At that time conservation was defined by Gifford Pinchot, the Chief Forester, as the wise use of our forests, waters, soils, and ores (mineral resources). A little later *wild life* was added as a fifth resource and subsequently the *human* resource was taken under the expanding wing of conservation.

With the experience of three decades we might now define conservation as the management of all our natural resources so that the greatest good to the greatest number over a long-time program will result. Since the great majority of the American people know little and care less about *any long-time* program it will be many more decades before real conservation can be put into general practice. However, if organizations such as this Academy understand the need and advocate the practice of conservation, the future leaders of State and Nation will be better informed, and inspired to do the right thing by the abundant gifts with which this country has been blest.

We now seem to have two schools of conservationists, each of the opinion that its point of view is the true one. The practical man bases his opinions on the *economic* use of our natural resources; and *sometimes* this use is based on *commercial demand* rather than on *public need.* And though this man, who favors "wise use," at times fails to look far enough ahead, his policy, improved with knowledge, must no doubt govern the management of the bulk of our resources.

Strongly opposed to this point of view is the aesthetic conservationist, he who would preserve the beauty of the forest or waterfall by prohibiting or greatly limiting its economic use. This man puts recreation and enjoyment first and on him we depend chiefly to save our beauty spots; while the other puts ahead the plain drab need of making a living. Neither questions the *need* of the other but each insists that *his* policy is the more important.

If this question is to be determined by the pressing immediate needs of the *private landowner* and the *two-year* view of succeeding legislatures, we shall, I fear, continue to neglect the *long-time* view and our conservation practice will continue to remain ineffective until the resources have disappeared.

In addition to these two opposing view points of conservation there is to my mind a third which may be considered a combination or a com-

* Fernow's History of Forestry, page 431.

promise or a way out, which we might call the *ethical* point of view. Many people who have thought as well as searched, have faith and conviction that there is a master mind behind this matter and that there is a divine plan of growth, improvement, and development which we call evolution. Recognizing the existence of such a plan, should we not work with Nature as closely as our actual needs will allow, protecting and preserving for future generations all economic and aesthetic resources in at least as good condition as they came to us from the past? By destroying or even materially reducing in one generation any such natural resource we are defrauding our descendants to infinity, which is worse than simply defrauding our neighbour.

However, let us now come down to a few present day problems. First a few words about the policy of Stand Improvement on National Forests, which was the primary cause of the appointment of this committee two years ago. The National *Forests* are administered on an *economic* basis as opposed to the *aesthetic* interests of the National *Parks*. The primary values of the National Forests are regulation of stream flow and production of timber. The large majority of forest land, both publicly and privately owned, *must* be handled as a *crop* for the production of revenue, and as the farmer considers those plants weeds which injure the desired farm crop, so the forester considers those species weeds which interfere with the development of the *salable timber* crop. This is the justification for the cutting out of dogwood and other of the less valuable species in order to favor the more valuable ones, which is, as just mentioned, an accepted practice by farmers growing annual crops. This *policy* must meet our approval, though sometimes its *practice* does not. Forestry in this country is in its infancy and no owners of forest land are in a position to act with full knowledge of what the final results will be, as full information on growth, future markets, and other factors is not yet available.

The conservation of our scenery is a problem that our people are only just waking up to. The efforts of the various states to secure tourist travel and desirable settlers emphasize our need for the protection of what natural scenery we have. While economic necessity seems to demand the construction of highways, telephone lines, and other improvements across the landscape, a growing desire for beauty will demand the restriction of these and other so-called improvements in many areas. It is only through the education of the public that improvement in this respect will come about and the primary object of this report is to ask the coöperation of members who are educators in emphasizing the principle of conservation in every line of endeavor.

The need for conserving the supply of our food fishes is well illustrated by the very serious decline in our shad fisheries. We have expended large sums of public as well as private money in the construction of locks, dams, etc., across larger streams without any thought or care that this would keep the shad from their spawning ground. Unless every precaution is taken similar destruction of other food fishes will be caused in our waters by the rapidly expanding pulp industry and the consequent pollution of our streams.

Another serious problem is the destruction of wild life under ill-advised State and Federal laws favoring the group known as game. Conservation to many sportsmen, as well as to the makers and purveyors of arms and ammunition, seems to mean the artificial production of a few game birds and the destruction of all birds and animals which they consider inimical to the sportsman's interest and class as predators and vermin. A recent very determined attempt to secure legislative authority in one of our eastern counties for the indiscriminate hunting and killing of bear, muskrats, rabbits, and foxes at any time and without a license, and to allow the poisoning of crows and jackdaws is a nearby instance of misguided enthusiasm for the conservation of one resource at the expense of another.

Wild life administrators are rapidly coming to the conclusion that the artificial production of game birds is no solution to the growing scarcity of game species. The conservation of their natural feeding and breeding areas, with the restoration, so far as possible, of what we refer to as the "balance of nature" is the only practicable policy.

There are many problems confronting public officials responsible for the administration of our natural resources which must depend on scientific research for their solution. North Carolina will continue to count on the coöperation of the scientists of the State in such public service. However, the great task before us is the conversion of a wasteful and indifferent public, to one recognizing its duties to the future, before it is too late.

Conservation cannot be superimposed on a State or Nation by just changing the name of one Federal Department, which has been notorious for its dissipation of our natural resources, to the Department of Conservation, and taking to itself other government agencies already deeply interested in and practising various phases of conservation; but the principle must be drilled or instilled into our people, especially our young folks, as they gradually accumulate knowledge about our re-

sources. While every citizen has his responsibility for handling those resources which come into his care in a conservative way, realizing his full responsibility to the future, it is more especially the task of those who are studying nature and are teaching the youth of our land to emphasize at every opportunity the responsibility which the handling of our natural resources places upon each one of us. For this reason I feel that this Academy can well encourage among its members not only research and study of our natural resources but coupled with it the training of their students and the public in the *wise use* of these resources."

The report of the conservation committee was approved and the secretary was authorized to order 250 reprints of this report when published.

The committee on the A. A. A. S. grant, consisting of R. E. Coker, chairman, M. L. Braun, O. J. Thies, J. G. Boomhour, and Eva G. Campbell, reported:

"That the A. A. A. S. grant for 1936 was awarded to Mr. D. S. Correll for his 'Studies on the orchids of the southeastern states,' and that the grant for 1937 be awarded to L. G. Willis for the continuation of his studies on 'The oxidation-reduction equilibrium in soils.' A special request was made that more applications be sent in for this grant."

The report of the committee on the A. A. A. S. grant was accepted.

A memorial report honoring the late Dr. David H. Howard, Jr., was presented:

DR. DAVID HALBERT HOWARD, JR.

"David Halbert Howard, Jr., passed to his eternal home on April 26, 1936. In his passing his devoted family in Virginia was overwhelmed in grief, Davidson College suffered an irreparable loss, and this Academy has lost one of the most brilliant young men who ever came to North Carolina to contribute his energies to the advancement of science.

"David Howard was born in Lynchburg, Virginia, on June 23, 1906, with a social background that fitted him for rare attainment in scholastic achievements.

"At the age of eighteen years he graduated from the Lynchburg High School at the head of his class.

"The following fall he entered Davidson College, became a popular

student on the campus, and early in his college course was outstanding in literary and scholastic activities.

"He was a member of the Eumenean Literary Society, the International Relations Club, Omega Phi Alpha, Gamma Sigma Epsilon, and Phi Beta Kappa. He was a leader of the Sigma Phi Epsilon Social Fraternity and contributed largely toward placing this Fraternity first in scholarship at Davidson College.

"He graduated at Davidson as valedictorian in his class and won many honors during his college course, notably membership in Phi Beta Kappa and likewise in Gamma Sigma Epsilon, an honor Chemical Fraternity. His leadership in the above Chemical Fraternity brought to him the high honor of being elected as a Grand Officer.

"After his graduation in college he accepted a place as instructor in Chemistry at his alma mater which gave him opportunity of making this one of the most fruitful years in his study of Chemistry. When he completed this year's work, he took up graduate work at Cornell University. He was a teaching assistant at Cornell in 1930 and received a fellowship each year afterwards until he was awarded his Ph.D. degree in 1933.

"Conspicuous honors fell to him at Cornell, being elected to membership in Sigma Xi, Alpha Chi Sigma, and Phi Kappa Phi.

"From 1933 to 1935 he was an assistant professor at George Washington University and received a call as associate professor of chemistry at Davidson College in 1935.

"His rare combination of geniality, sincerity, high ideals as a teacher, and his unselfish zeal in helping and encouraging students made him a much liked teacher from the very start, and he promised to make a professor in the college, outstanding in character, service, and personality.

"As proof of his zeal in science, we cite the fact that during his first year as professor at Davidson he joined the North Carolina Academy of Science and the American Chemical Society.

"Already he, in conjunction with one of his colleagues at George Washington University, published a laboratory manual in general chemistry and a number of articles were published in the Journal of the American Chemical Society.

"Truly a gracious and beautiful character has passed on to his award.

"May his unselfish conduct, his uplifting influence, and his noble example continue to bless his loved ones and his friends through the eternal years.

"The Academy deeply mourns his loss and extends sincerest sympathies and condolence to his bereaved family."

H. B. ARBUCKLE,
W. L. PORTER,
O. J. THIES, JR.
Committee.

Bert Cunningham, representative of the Academy to the A. A. A. S. reported as follows:

"Some thirty representatives of the various academies attended the Academy Conference for 1936–37. The program consisted largely of the reports of the activities of the various academies in addition to their usual annual programs. A number of academies reported especially helpful relations with Junior Academies. It became evident during the progress of the meeting that there were important problems which academies should face, such, for example, as securing funds for research, initiating suitable legislation for academic freedom, and providing proper publication for scientific work. The dinner given by the A. A. A. S. was well attended. Dr. Bilsig was re-elected as secretary for a three year period.

"The Council this year handled only matters of routine. The organization of a southern-eastern section of the Association was not brought up. A full report of the Council actions has already been printed in *Science*. Richmond has been selected as a meeting place for 1938–39 and it is to be hoped that the members of this Academy will aid in every way possible to make that meeting a success."

The general resolutions committee, consisting of J. P. Givler, chairman, R. J. Campbell, and E. E. Randolph, presented the following resolution:

"The North Carolina Academy of Science wishes to express its great appreciation of the manner in which it has been entertained by Catawba College.

"We desire to express our thanks for the hospitality of the College at the complimentary supper, at the dramatic entertainment, and the reception, and for the gracious manner in which the students of Catawba College assisted in the registration and in the posting of the progress of the papers of the different sections during the meeting."

The nominating committee submitted the following nominations:

President: W. E. Speas, Wake Forest College;

Vice-President: M. L. Braun, Catawba College;

New member of the Executive Committee (for three years): R. F. Poole, North Carolina State College of the University of North Carolina;

Two new members of the Committee of the A. A. A. S. Grant (for three years): G. W. Hargitt, Duke University, R. N. Isbell, Wake Forest College;

Representative to the A. A. A. S.: Bert Cunningham, Duke University.

The nominations were accepted and the secretary was instructed to cast the ballot of the Academy for the nominees.

The president then announced the appointment of the following committees:

The Legislative Committee: H. F. Prytherch, chairman, B. W. Wells, W. F. Prouty.

The Conservation Committee: J. S. Holmes, chairman, J. P. Givler, C. F. Korstian, W. C. Coker, H. J. Oosting.

The High School Science Committee: Bert Cunningham, chairman, H. B. Arbuckle, Mrs. B. W. Wells, C. E. Preston, R. J. Campbell, Mary Conrad Cleaver.

The Committee on the Phipps and Bird prize: J. N. Couch, J. B. Derieux, J. P. Givler, Annie Pegram, O. J. Thies, F. A. Wolf.

The Elective Appraisal Committee: to stand with no changes.

The business meeting then adjourned.

At 6:30 the Academy and visitors were entertained at a complimentary barbecue supper on the College Campus.

At 7:30 the local dramatic club entertained the Academy with a one act comedy, "There are none of them perfect."

At 8:30 the evening meeting was held with the vice-president, C. F. Korstian, presiding. The address of welcome was made by Howard R. Omwake, president of Catawba College. This was followed by the presidential address, entitled "The Interdependence of the Sciences," by the retiring president P. M. Ginnings.

On Saturday morning the Academy met in sections. Vice-president C. F. Korstian presided over the General Section; J. M. Clarkson over the Mathematics Section; and Milton L. Braun over the Physics Section. The North Carolina Section of the American Chemical Society did not hold a meeting at this time and the election of officers was done by mail.

The following officers were elected by the respective sections:

Mathematics Section: Chairman, J. J. Gergen, Duke University; Secretary, Archibald Henderson, The University of North Carolina.

Physics Section: Chairman, J. B. Derieux, North Carolina State College; Secretary, F. W. Lancaster, North Carolina State College.

North Carolina Section of the American Chemical Society: Chairman, W. C. Vosburgh, Duke University; Vice-President, R. N. Isbell, Wake Forest College; Secretary-treasurer, E. C. Markham, The University of North Carolina; Councilors, D. G. Hill, Duke University; R. W. Bost, The University of North Carolina; Executive Committee, the officers and C. S. Black, Wake Forest College; W. A. Reid, North Carolina State College; Edward Mack, the University of North Carolina; W. E. Jordan, North Carolina State College.

The following papers were presented. Those marked with * appear in full in this issue; those marked x are abstracted with the Proceedings; those marked † were read by title.

GENERAL SECTION

Additional Sources of Androsterone. M. D. KRITZER and BERT CUNNINGHAM, Duke.

†x *Caves of Yucatan.* A. S. PEARSE, Duke.

†x *A Photoelectric Device for Rapid Measurement of Leaf Areas* (Lantern). PAUL J. KRAMER, Duke.

**Development of the Perithecium of the Ascomycete, Sordaria fimicola* (Opaque Projector). DON RITCHIE, U. N. C.

Paraffin Crystals: Spiral and Other Forms (Lantern). CHARLES M. HECK, N. C. State.

Methods of Research in Soil Fertility (Lantern). L. G. WILLIS, N. C. State.

**A Fungus that Catches Nematodes* (Lantern and Opaque Projector). JOHN N. COUCH, U. N. C.

A New Species of Rozella Parasitic on Allomyces (Lantern). FRANCES K. FOUST, U. N. C.

Published in full in this Journal **53**: 197–204. 1937.

Surface Tension of Water at Low Pressures (Lantern). A. A. DIXON, N. C. State.

The Primary Wall of the Cotton Fiber (Lantern). DONALD B. ANDERSON, N. C. State.

Secondary Wall Deposition in the Cotton Hair (Lantern). THOMAS KERR, N. C. State.

Survey of the Fungi of the Duke Forest. FREDERICK A. WOLF, Duke.

Cytological Observations on Thraustotheca clavata (Lantern and Opaque Projector). LELAND SHANOR, U. N. C.

Published in full in this Journal **53**: 119–136. 1937.

x *Direct Appraisal of Available Cellulose in Wood for Pulp Yields.* E. E. RANDOLPH, N. C. State.

x *The Wind as a Sorting Agent.* G. R. McCARTHY and J. W. HUDDLE, U. N. C.

x *Endosperm Development in the Araceae* (Lantern). MURRAY F. BUELL, N. C. State.

Varietal Differences in the Vitamin C Content of Tomatoes (Lantern). G. HOWARD SATTERFIELD and FRANCIS TRIPP, N. C. State.

Oedocladium Lewisii, a New Green Alga (Lantern). L. A. WHITFORD, N. C. State.

Mileage of Different Gasolines and at Different Speeds (Opaque Projector). J. B. DERIEUX, N. C. State.

Wintering of Honeybees in North Carolina: Some Recent Results (Lantern). F. B. MEACHAM, N. C. State.

x *Influence of Parathyroid Extracts on Growing Bone.* ROBERT B. BURROWS, Elon College.

x *"Permian."* WILLARD BERRY, Duke.

x *Notes on Buckleya and Pyrularia (Buffalo-Nut).* H. R. TOTTEN, U. N. C.

Archaeology in North Carolina. JOFFRE L. COE, U. N. C.

x *Granite Intrusion in Eastern Wake County, North Carolina.* JOHN M. PARKER, N. C. State.

x *Volcanic Rocks in the Eastern Piedmont of North Carolina.* J. L. STUCKEY, N. C. State.

x *Control of the Oyster Drill (Motion Picture).* HERBERT F. PRYTHERCH, U. S. Bureau of Fisheries, Beaufort.

Effect of Some Fats on Gastric Motility (Lantern). HERBERT C. TIDWELL, Wake Forest.

x *Asheville, a Study in Urban Geography.* MARTHA E. NORBURN, Biltmore.

x *A New Qualitative Test for Selenium.* H. A. LJUNG, Guilford College.

Air Cells in Snow Crystals and Other Forms of Ice (Lantern). CHARLES M. HECK, N. C. State.

x *Lactogenic Substance in Reptile Pituitaries* (Lantern). BERT CUNNINGHAM, Duke.

Utilization of Whole Cotton. FRANK K. CAMERON, U. N. C.

x *The Nomenclature of Fractures.* GROVER MURRAY, U. N. C.

MATHEMATICS SECTION

The Symbolic Calculus of Two Variables Applied to the Heat Equation. F. G. DRESSEL, Duke.

x *On the Classification of Collineations.* J. W. LASLEY, JR., U. N. C.

Lebesgue Integrals and Riemann Sums. J. J. GERGEN, Duke.

**A Century Old Problem in Euclidian Geometry: A Basic Study with Ten New Solutions.* ARCHIBALD HENDERSON, U. N. C.

x *Sets of Conjugate Matrices.* E. T. BROWNE, U. N. C.

PHYSICS SECTION

x *Chemical Analysis by Means of Infrared Spectra* (Lantern). E. K. PLYLER, U. N. C.

The Effect of Pressure Changes on the Appearance of the High Frequency Glow Discharge (Lantern). SHERWOOD GITHENS, JR., Wake Forest.

Gasoline Mileage in Terms of Octane Rating and Volatility Number (Opaque Lantern). J. B. DERIEUX, N. C. State.

x *Cosmic Ray Showers Produced in Large Thickness of Various Materials* (Lantern). KARL Z. MORGAN and W. M. NIELSEN, Lenoir-Rhyne and Duke.

x *Plastic Give and Recovery in Stretched Neoprene* (Lantern). MILTON L. BRAUN, Catawba.

EXHIBITS

Photomicrographs of Paraffin Crystal Forms. CHARLES M. HECK, N. C. State.

Destruction of Oysters by Drills. HERBERT F. PRYTHERCH, Beaufort.

Influence of parathyroid extracts on growing bone. ROBERT B. BURROWS, Elon College.

North Carolina Shore Birds. FRAZER G. POOLE, Catawba College.

The following abstracts have been received:

Caves of Yucatan. A. S. PEARSE.

The caves in Yucatan are of particular interest because they have for centuries served as sources of water for Mayas and therefore played an important rôle in the development of Mayan culture. During the summer of 1936 twenty-seven caves were studied. Air temperatures ranged from 22.0° to 27.9°C; water temperatures, 22.0° to 27.2°C; humidities, 90.2 to 100%. Five species of fungi have been cultured by Dr. F. A. Wolf from debris brought from caves. Nineteen papers have been prepared by specialists on the animals collected, which include land planarians, trematodes, cestodes, nematodes, oligochaetes, leeches, gastropods, copepods, ostracods, shrimps, isopods, schizopods, thysanurans, collembolans, cave crickets, cockroaches, beetles, flies, mosqui-

toes, ants, wasps, parasitic hymenopterans, fleas, millipedes, centipedes, spiders, mites, ticks, whip scorpions, pseudo-scorpions, fishes, lizards, snakes, and mammals. Most of the types collected were trogloxenes, but there were some troglophiles and troglobites. Blind species included shrimps, isopods, schizopods, collembolans, ants, millipedes, mites, brotulid fishes, and a symbranchid eel.

A Photoelectric Device for Rapid Measurement of Leaf Areas. PAUL J. KRAMER.

By the use of a photoelectric apparatus leaf areas can be measured much more rapidly and with nearly as great accuracy as by any of the methods ordinarily used. The leaves are placed on a ground glass plate interposed between a light source and a photoelectric cell which is connected to a microammeter. The deflection of the microammeter is inversely proportional to the amount of light intercepted and hence to the area of the leaf or leaves. By plotting the microammeter readings for pieces of leaf of known area a curve can be drawn from which the area corresponding to any observed reading can be quickly determined. The apparatus described by the writer has two improvements not found in those previously described. A cone of polished aluminum was inserted between the ground glass plate and the photoelectric cell. This concentrates the light on the cell so that a light source of much lower intensity can be used. It also reduces positional error. A resistance was inserted in the light source circuit permitting adjustment of the light intensity to compensate for variations in line voltage. These features have appreciably increased the accuracy and made it possible to use the apparatus in spite of considerable variations in intensity of the light source.

Direct Appraisal of Available Cellulose in Wood for Pulp Yields. E. E. RANDOLPH.

The interest in pulp and papermaking in the South has been greatly increased during the past year. At present companies are erecting ten large new pulp mills; one in Virginia, one in North Carolina, two in South Carolina, two in Georgia, two in Florida, one in Arkansas and one in Texas. Two of these mills are just beginning operation. It is reported that the total cost of these mills is over sixty-six million dollars. Negotiations are in progress concerning the building of other mills for pulp and news-print paper in the South. There are several reasons for such large investments in new paper industries. The longer growing

season and the fertile soil account for the rapid growth of timber to marketable size within about twenty years, whereas in northern latitudes trees must become thirty-five or forty years of age before they are of marketable size. The climate assures all year round operation at full capacity. There are ready markets. There is a plentiful supply of suitable water. There are good highway, railway, and water shipping facilities. There is a sufficient supply of skilled and common labor. Already an enormous supply of pulp and paper is being produced in the South. In North Carolina, for example, is located one of the largest paper mills in the world producing daily between four and five hundred tons of pulp and paper and there are in active operation also two other paper mills in the state.

The essential part of wood for pulp making is cellulose. This material forms cell walls of plants. There are in plants and trees various other constituents besides cellulose. In order to make good paper, it is necessary to remove the other constituents from the wood and leave the cellulose in as pure form as possible. In the mechanical process for making pulp none of the other constituents is removed from the cellulose. The total weight therefore of the dry log goes into pulp. In the chemical process, however, the other constituents are removed from the cellulose to a greater or less extent so that from 50 to 60 per cent of the weight of the wood yields pulp.

The purchasing agent of the company buys lots of wood on the basis of the cellulose content in the wood which can be realized in the digester yields. It is important that a reliable method may be available to determine the cellulose content of the wood which may reasonably be expected to represent the yields which can actually be made on the plant runs in the mill. Different methods have been devised for determining cellulose content of the plants. The most important of these methods is the Cross and Bevan method. Unfortunately, this method takes considerable time and does not always gives yields which can be duplicated in the plants. The importance of a method which does give results comparable to what may be expected in plant yields is apparent. The object in this investigation was to see if a direct method could be devised which would be accurate, dependable, and capable of being performed in a short time.

This research was carried on in the Chemical Engineering Department of State College during the year and satisfactory results were obtained. The plan pursued is to build a small constant temperature oil bath regulated by automatic control so that the temperature does not vary

more than one-half of one degree. Small stainless steel digesters are used. The wood under examination is sawed with a coarse circular saw and the sawdust is carefully screened. It is then placed in autoclave with the digestive liquor. In this work the sulphite liquor was used. Time is gained by using sawdust rather than the commercial size chips in the digester. The digestive liquors penetrate the chips in a digester by capillary action. It is slow in permeating the interior chips. By having sawdust instead of chips the penetration of the liquor is rapid. In this way an actual cook of the wood can be made within three or four hours whereas the Cross and Bevan method required two to three days work. The outfit is reasonably small and portable and can be taken from place to place and used wherever electric current is available to run the motor and operate the automatic electric heat device. The purchaser therefore can with a small amount of trouble make a determination on a cellulose content of the wood which will give him such information that he can pay the farmer a price on the assurances that he can duplicate the yields in cellulose in the plant operation. The farmer can be assured that he is receiving the full pay for the value of his wood. A sufficient number of digestions and examinations were made to satisfy ourselves that this direct appraisal method gives accurate and dependable results.

The Wind as a Sorting Agent. G. R. McCARTHY and J. W. HUDDLE.

It is well known that the grains of dune sands are rounder than the grains of beach sand, and this difference is usually ascribed to greater abrasion (caused by mutual attrition) suffered by the wind-blown sands. Field evidence shows that dune sands which have been shifted too short a distance by the wind to have suffered appreciable abrasion are nevertheless distinctly rounder than the beach sands from which they were derived. Experimental evidence has now been obtained which shows that the superior roundness of dune sands is largely due to a selective action by the wind, the rounder grains moving more readily and hence being concentrated in the dunes. This movement under the influence of the wind does not seem to be one of rolling, but rather one of jumping, or saltation, the individual leaps of the rounder grains carrying them farther than the more angular ones.

Endosperm Development in the Araceae. MURRAY F. BUELL.

Of the three types of endosperm development, the nuclear type in

which endosperm formation is initiated by a period of free nuclear division, is the most common in the angiosperms. The cellular type, in which each division from the very first is accompanied by wall formation, is much less common. A third, the basal apparatus type, is often spoken of as the Helobiae type since it is so characteristic of that group. In this type at the first division of the primary endosperm nucleus a wall is laid down dividing the embryo sac into two cells. In each of the resulting two cells further endosperm development is different. The micropylar cell may have nuclear or cellular endosperm while the basal cell may remain undivided and even enlarge into a huge haustorial cell. Nuclear endosperm may be produced or even cellular endosperm but always this basal apparatus is of distinctly different nature from the rest of the endosperm. That the basal apparatus may sometimes be even more fundamentally different is indicated by a study of *Acorus Calamus* in which the basal cell is apparently cut off before the pollen tube enters. If double fertilization does occur then the tissue produced in the upper cell is triploid and that in the basal cell is diploid.

Influence of Parathyroid Extracts on Growing Bone. ROBERT B. BURROWS.

Studies were made of the effects of two different parathyroid extracts on the bones of immature albino rats with the purpose of observing the detailed changes in the bones and the probable method of mobilization of the excess calcium found in the blood during hyperparathyroidism. Parathyroid extracts cause a condition of osteitis fibrosa just as does hypersecretion of the parathyroid glands. This, however, soon gives way to a different condition, called "marble bone disease," which consists of hypercalcification rather than a fibrous state, and is not characteristic of true hyperparathyroidism.

Although Collip's and Hanson's extracts are supposed to affect blood calcium to the same extent, they do not affect bone to the same degree, when given in equivalent doses. Collip's is much more pronounced in its effects.

Osteoclastic activity appears to follow decalcification and not to be the cause of it during the production of osteitis fibrosa. The underlying causes of decalcification, anti-extract formation, production of marble bone disease, and subsequent events appear to be chemical in nature and to be due to the impurities in the extracts. Since parathyroid extracts do not duplicate true hyperparathyroidism, but bring

into prominence several anti-body-like activities, they should be used with more caution in therapeutics and conclusions derived from experimental work should be evaluated carefully.

"Permian." WILLARD BERRY.

The Permian in eastern North America was separated from the Upper Carboniferous in the year 1880 by Fountain and I. C. White on the basis of the fossil plants found in the Cassville shale which lies on top of the Waynesville No. 11 coal. It has been recognized that the location of this boundary was more or less arbitrary but at that time no other evidence was available. Recently this boundary has been subject to discussion and various lines of evidence have been advanced either to prove its location or to change it, up or down in the section. In this instance the author advances the possibility that due to the appearance of red beds in the middle Conemaugh the boundary should be moved down to the base of that horizon; by explaining the occurrence of the red beds as evidence of organic movement or of a climatic change consequent upon organic movements of considerable magnitude to the eastward.

Notes on Buckleya and Pyrularia (Buffalo-nut). H. R. TOTTEN.

Herbarium specimens were shown and the history and distribution of what W. W. Ashe called "our largest known American parasite," *Buckleya distichophylla* (Nutt.) Torr., was reviewed. Previously it had been reported only from the banks of the French Broad River in east Tennessee and in North Carolina and from the banks of the Pigeon River in Haywood County, North Carolina. A new location and state for this interesting plant was reported, viz., the bank of Dismal Creek in Bland County, near the Giles County line, in Virginia, where with a class from the Mountain Lake Biological Station of the University of Virginia, we found it growing under *Tsuga canadensis.*

Herbarium specimens were also shown of *Pyrularia pubera* Michx. This plant has a rather wide distribution through the mountains and upper piedmont of our region. It is found associated with quite a variety of plants and its rather elaborate underground runner system, connecting what at first appears to be separate plants, shows little connection with the surrounding plants. While not questioning the proof that it is sometimes a parasite, the question is again raised as to whether it is an obligate parasite or can also exist independently.

Granite Intrusion in Eastern Wake County, N. C. JOHN M. PARKER, III.

Preliminary work on the detailed mapping and description of the geology of Wake County, by Dr. J. L. Stuckey and the writer, has brought to light a number of structural features related to a Carboniferous granite batholith. The eastern third of the county is underlaid by biotite granite, intruded into Pre-Cambrian gneiss, schist, slates, and metamorphosed volcanic rocks. The boundary lines of the granite are regular, straight, and nearly always parallel to the foliation in the walls. The country rock has been much altered by lit-par-lit injection between the laminations, by soaking with granitic solutions, by the intrusion of a net-work of pegmatite dikes and quartz veins, by the development of fracture cleavage dipping at 20–25 toward the intrusion, and by displacement along small thrust faults in the same position. The granite contains abundant inclusions in a zone some two miles wide along both sides. Individual inclusions range up to half a mile wide by two miles long, and are granitized and crumpled. The planes of flowage of the magma are well preserved in the parallel orientation of biotite flakes, tabular feldspar crystals, and small inclusions. They tend in most instances to be vertical or to dip eastward at high angles, and to be parallel to the contacts and the foliation of the walls. The intrusion is composite, being in places gray and even-grained, in others gray, coarse and porphyritic, and in one area pink from abundant microcline. The presence of zones of excellent flow banding and marginal thrusts in the interior of the granite indicate that these varieties represent separate intrusions in a composite batholith.

Volcanic Rocks in the Eastern Piedmont of North Carolina. J. L. STUCKEY.

Volcanic rocks, all of pre-Cambrian age and the same general physical characteristics, occur in three distinct areas along the eastern part of the Piedmont Plateau.

First, and most important, is the slate belt which crosses the state in a general northeast-southwest direction and varies in width from 20 to 60 miles. The slate belt includes parts or all of the counties of Union, Stanley, Montgomery, Davidson, Randolph, Chatham, Orange, Durham, and Person.

The second area is a narrow zone along the western parts of Wake County, crossing the east central part of Granville and the northwest corner of Vance.

The third area is represented by a series of out-crops along the western edge of the Coastal Plain. These out-crops are exposed chiefly along the river valleys eastward as far as Weldon, Rocky Mount, Goldsboro, and Erwin.

Recent field work by the writer indicates that the extent of these volcanic materials along the western part of the Coastal Plain is much more extensive than indicated on any published map or in any available reports. It seems very probable that the whole western part of the Coastal Plain as far east as Erwin, Goldsboro, Rocky Mount, and Weldon is underlaid with volcanic rocks. Between streams these are covered with a thin veneer of Coastal Plain material. The strike-and-dip of the cleavage in these rocks varies widely from place to place, indicating that the processes of metamorphism have been exceedingly complex in these areas.

Control of the Oyster Drill. H. F. PRYTHERCH.

Two species of marine snails, *Urosalpinx cinerea* and *Eupleura caudata* destroy seed and adult oysters valued at several million dollars annually. Investigations conducted in the Seaside region of Virginia and in North Carolina show that control of these drills or borers is possible by means of traps and by their removal during oyster culling operations. Drills are strongly attracted to seed oysters which are used as bait in traps made of chicken wire. The traps are arranged at intervals of 10 feet on a 250 foot rope line, which is fished weekly and the drills removed by vigorous shaking.

In experimental trapping operations a total of 320,880 drills (78.6 Urosalpinx and 21.4 Eupleura) were collected by the use of 4,750 traps over a period of 3 months. The most efficient procedure is to operate each trap line in successive radial positions with one end of the line stationary. By shifting the line 45 degrees after each fishing it is possible to remove virtually all of the drills from 4 acres of bottom in approximately 3 months.

Field studies of the drill population on representative tidal flat areas indicate that there are over 35,000,000 of these pests on the public and private oyster beds of the Seaside region. Studies of the rate of feeding of drills, conducted under natural conditions show that 100 drills can destroy over 125 seed oysters and 90 adult oysters in one month. Therefore, it is possible for the drills of this region to destroy nearly half a billion seed and adult oysters in one summer season. The depleted condition of the natural beds and the poor yield from oyster

cultivation operations in this section is due primarily to the destructive habits of these pests.

Asheville: A Study in Urban Geography. MARTHA E. NORBURN.

Although so isolated by mountain barriers that settlement was delayed until after the Revolution, Asheville has become a cosmopolitan city. It owes its growth to its commanding position at the convergence of communication routes in the heart of the Southern Appalachians.

English and Scotch-Irish pioneers penetrated rugged passes in the rim of mountains; followed animal and Indian trails whose pattern was determined by range, gap, and stream; built cabins; and, in 1792, organized Buncombe County.

The county seat, Morristown, was located near the confluence of the Swannanoa and French Broad rivers and at the crossing of the east-west and north-south trails. Population increased through the desire for land; through health seekers who found the climate of subdued mountains in the Virginia belt beneficial; and through scientists who came to study landforms and vegetation.

In 1797, the village of Morristown became the town of Asheville. Stock driving from the Mississippi Basin to the Atlantic Seaboard, the tobacco boom, and the railroad combined to increase population. In 1883, Asheville was created a city. Its growth has since been augmented by industries and by roads which serve the National Forests and the Great Smoky Mountain National Park.

The business zone has been altered to accommodate traffic, the "Square" dedicated to the crossing of highways, and a mountain tunneled. The pattern is still radial and conforms to the topography.

A seasonal population travels the roads. However, as the gaps and ancient trails control the communication pattern, the descendants of the English and Scotch-Irish pioneers determine the permanent pattern of population.

A New Qualitative Test for Selenium. H. A. LJUNG.

Within the past few years the element selenium has commanded considerable attention. It has been shown that plants take up selenium from soils in which it occurs, and that the plants which have taken up the selenium are toxic when used as foods for animals. Dr. Knight,[1] Chief of the United States Bureau of Chemistry and Soils, tells interestingly of the selenium problem in this respect. He relates that such

[1] Knight, H. G.; Sigma Xi Quarterly **25**: No. 1, 1937.

diseases as "alkali disease" and "blind staggers" are due to selenium poisoning, and that thousands of cattle and sheep succumb annually from eating plants which contain selenium. Dr. Franke of the South Dakota Experiment Station, now deceased, also writes of his experiences and researches on this problem.[2]

In addition to the attention selenium has attracted from this quarter, it has found use in the production of stainless steels.

This great selenium problem of the west and the uses of selenium in steels has attracted the attention of the analytical chemist, and as a result new methods for the qualitative detection and quantitative determination of the element have been developed. The methods commonly employed are the distillation method using bromine-hydrobromic acid solution, and the reduction methods using such reducing agents as sulfur dioxide, potassium iodide, etc. The reducing agents commonly employed are unsuitable as standard solutions, hence a reagent which is stable and can be conveniently standardized would be more desirable.

The use of the thiocyanate ion as a standard reducing agent in other analytical reactions has suggested its possible use as a reagent for the reduction of selenious acid. No references are available in the literature concerning such a reaction, and no theoretical considerata are available concerning the possibilities of the reaction taking place, hence it was necessary to try out the possibility experimentally. It was found that the thiocyanate ion is capable of reducing the selenite ion in solutions acid with hydrochloric acid. (The reaction also takes place in solutions acid with sulfuric acid; however, as yet this work is incomplete. A report will be made later concerning the reaction in sulfuric acid solutions.) The selenium is precipitated as red metallic selenium in high concentrations of selenium; as a yellowish green precipitate in low concentrations; and as an almost white precipitate in exceedingly low concentrations. The precipitate is usually finely divided, remaining suspended for almost an hour. Hydrogen sulfide is also one of the end-products of the reaction. Unfortunately this work has not progressed far enough to permit the writing of an equation to represent the reaction between the ions. However, work has been done which reveals some of the properties of the reaction, as follows:

(1) The reaction takes place rather slowly and incompletely in solutions less than six normal in hydrochloric acid. At higher concentrations of acid the reaction proceeds rapidly and quantitatively.

(2) The reaction takes place only slowly at room temperature—re-

[2] Franke and Painter, Ind. Eng. Chem. **29**: 591-95, 1937.

quiring more than thirty hours for completion when as little as 2.5 mg. of selenium is present. The reaction proceeds rapidly at temperatures above 60°C.; and is quite rapid at the boiling-point of the solution—requiring only 20–30 seconds for completion with small quantities of selenium.

(3) Volumetric relationships indicate that there is a stoichiometric ratio between the ions involved.

(4) The reaction may be carried out in the presence of the common metals, with the exception of divalent iron, divalent tin, and trivalent antimony.

(5) The reaction is capable of detecting as little as 1 part of selenium in 38,000,000 parts of solution.

Having learned these properties of the reaction, attempts are now being made to discover an equation which represents the reaction between the ions. Attempts are also being made to apply this reaction to the quantitative determination of selenium in soils, plants, and steels.

Lactogenic Substance in Reptile Pituitaries. BERT CUNNINGHAM.

As is well known, the pituitary is the seat of secretion of a variety of endocrinal substances; the number accepted depending upon the school to which one belongs. There seems to be little doubt however as to the validity of prolactin.

Since the chemical formula of this substance has not been determined, and since the identity of the material in the turtle pituitary has not been established, it seems preferable to use the term lactogenic substance in this paper.

Prolactin is rather unique in that it produces responses of considerably different natures and upon different organs in birds and mammals. In pigeons and doves it affects the crop glands and in the latter the mammary gland, two structures which have nothing in common in origin. In the hen, which has neither the crop gland nor mammary glands, injection of prolactin produces, according to Riddle, a broodiness, which has led to the idea that it is a sort of maternal-instinct gland.

Since reptiles for the most part have no interest in their young, and since mating procedures are dependent upon secretions from gonad and pituitary (G. S. H.) it was thought worth while to look for prolactin in reptile pituitaries, and if found, to make more or less crude assays.

This has been done in five species of turtles, namely *Terrapene carolina, Chrysemys picta, Pseudemys troosti, Pseudemys hieroglyphica,* and *Pseudemys elegans.* The animals of the first two species were taken on

Long Island while the others were secured from the Carolina Biological Supply House. The pituitaries of the *T. carolina* were preserved in acetone for several weeks; those of the latter were either implanted immediately on removal or kept frozen until used.

Although the local stimulation technique may demonstrate smaller quantities of the factor, it seemed better to follow, in general, the crop-gland weight technique of Riddle in these experiments. Subcutaneous implants were made over the breast muscles. The results are shown in the accompanying table.

PROLACTIN IN TURTLE PITUITARIES

SPECIES	Date taken	Average weight of implants	Number of implants	Test animal	Mg. of pituitary per unit
		mg.			
*T. carolina**	June	3	5	Pigeon	1.0
C. picta	Aug.	5	4	Dove	5.0
P. hieroglyphica	Sept.	12	5	Pigeon	1.0
P. troosti	March	10	5	Dove	10.0
P. elegans	March	5	5	Dove	5.0

* Preserved in acetone.

While these assays are not as accurate as they might be if made on an "endocrine stock" such as used by Riddle they show quite clearly that prolactin does occur in assayable quantities in the pituitaries of chelonians.

At a later time E. M. Nixon and Martha Tanner, working in my laboratory, demonstrated the presence of a lactogenic substance in the pituitaries of the pine lizard, *Sceloporus undulatus*, and in the turtle *Emys blandingi*. They also repeated the assays of the box turtle and painted turtle pituitaries and secured results comparable to my previous assay.

The presence of a lactogenic substance in the pituitaries, therefore, has been demonstrated for six species of turtles and one lizard. The assays while crude show a considerable quantity of the factor in the glands of these reptiles.

The Nomenclature of Fractures. GROVER MURRAY.

The lack of existing specific fault, joint, and fracture cleavage terminology has instigated the writer to attempt a revision of these terms

without introducing an entirely new system of nomenclature. Contemporary usage involves a combination of structural, genetical, dynamical, and geometrical terms. Obviously, a dynamical or genetical term or classification cannot precede a structural, descriptive, or geometrical one. The writer suggests, therefore, that use be made at all times of: (1) descriptive and suggestive terminology, (2) dynamical terms only after the causal stresses have been determined, and (3) terms related to local movement on faults as defined by the Geological Society of America's Committee on Fault Nomenclature.

Descriptive terms have been applied to joints and to fracture cleavage, and modifications have been made in many of the fault definitions. The writer urges that the terms be used as defined therein and that their descriptive, structural, and geometric bases be retained.

Since the report of the Geological Society of America's Committee on the Nomenclature of Faults, professional writers have largely standardized many fracture terms. Other terms, however, have failed to become standardized. These disputed terms have been re-defined as specifically as possible. Existing, undisputed terms have been assembled for completeness.

On the Classification of Collineations. J. W. LASLEY, JR.

This paper presents a classification of non-singular collineations in the plane by reducing all cases to a common canonical form in which the matrix is that of Jordan. Attention is directed to the collineation itself rather than to derived properties of it which may or may not be applicable to a particular case. Assumptions as to incidence relations among the double elements are avoided. Instead of proving, as is customary, a number of theorems relative to incidence, one such theorem is proved; namely, that all non-singular collineations in the plane have at least one double line and at least one double point on it. With this as a point of departure all collineations regardless of the nature of the roots of the characteristic equation and of the rank of the characteristic matrix are put into one common form, which exhibits incidence relations among the double elements common to all cases. The matricial setting of the problem is emphasized. Assumptions as to rank fall naturally into place. A fuller use of duality is made than ordinarily. The presence and the effect of the background of linear substitutions is pointed out. Incidence properties of the various cases follow naturally from the canonical expressions. Although avoiding the theory of elementary divisors, the treatment is that of algebra, utilizing geometry.

It makes available for the student a simplified first approach to the theory by developing the fundamental unity back of seemingly diverse conditions. It makes possible an easy remembrance of the canonical forms for the separate cases.

Sets of Conjugate Matrices. E. T. BROWNE.

If M is a given square matrix of order n, and if $M_1, \ldots, M_{t-1}$ are $t-1$ matrices of the same order which possess the following properties:

(1) The M's are commutative in pairs;

(2) If λ is a scalar and $f(\lambda)$ a scalar polynomial in λ such that the following identity holds:

$$(I) \qquad (\lambda - M)(\lambda - M_1)\ldots\ldots(\lambda - M_{t-1}) = f(\lambda),$$

then $M_1, \ldots, M_{t-1}$ are said to constitute a *set of conjugates* to M. If t is the smallest integer for which an identity of the type I holds, the set of conjugates is called a *reduced set.* Sets of conjugates have been studied by Taber, P. Franklin, E. Sokolnikoff, Pierce, Hermann and others. In this paper a thorough study is made of sets of conjugates and more general sets are obtained than those given hitherto. In particular, a special study is made of *cyclic* sets.

Chemical Analysis by Means of Infrared Spectra. E. K. PLYLER.

The line spectra of elements have been used to supplement chemical methods for the detection of the presence of elements. In the same manner infrared measurements can be used to detect the presence of molecules. Each molecule has a characteristic band spectrum. It has been found that an amount of 1/100 of one per cent water present in many organic liquids, such as the alcohols and acetone can be detected. By having a series of absorption curves for standard mixtures, the amount of water present in a liquid may be obtained. The work is being extended to include many different materials.

Cosmic Ray Showers Produced in Large Thicknesses of Various Materials. KARL Z. MORGAN and W. M. NIELSEN.

The apparatus used in these experiments consists of several Geiger-Muller counter outfits; each adjusted to register only coincident discharges of three or more counters. The data were recorded by electric relays on a moving tape.

The first series of investigations was made on Beech Mountain (elev. 4540 ft.). The variation of doubles with grams/cm.^{2} of lead above the

counters was found. An arrangement was used which gave an extremely low zero count of 6% of the maximum count. The experiments were repeated for iron absorbers. The maximums occurred at about 20 gm./cm.^{2} for lead and 50 gm./cm.^{2} for iron. The iron coincident counts at large thicknesses of scattering material were about 25% greater than for the lead.

A transition curve from iron to lead was obtained by placing various thicknesses of lead under 274.16 gm./cm.^{2} of iron. This curve indicated an initial rise to 13.12 gm./cm.^{2} of lead under the iron. Then there was a rapid decline in coincidences until about 100 gm./cm.^{2} of lead was placed below the iron. Beyond this point the transition absorption curve followed the lead curve characteristic.

The 13.12 gm./cm^2. of lead was placed above 274.16 gm./cm^2. of lead and there was no increase in counting rate above the normal iron count. This seems to indicate a secondary multiplication process by which the heavier elements produce more cosmic radiation for softer producing radiation;—the mean free path is shorter in lead for soft producing radiation.

The 13.12 gm./cm^2. of lead was placed below various thicknesses of iron. These points were plotted and connected and the general slope of this curve was the same as that of the iron curve.

Each material indicated a hard and a soft coefficient of absorption. The absorption coefficients of air radiation in lead were .03 cm^2./gm. and .0006 cm^2./gm.; of air radiation in iron they were .007 cm^2./gm. and .00044 cm^2./gm.; and of iron radiation in lead they were .009 cm^2./gm. and .0006 cm^2./gm. This seems to indicate a marked dependence of the absorption of this hard component of radiation upon mass.

The semi-log plot of the weak component of radiation was extrapolated and subtracted from the total coincident counts. This gave curves indicating second maxima of radiation. The second maxima were at about 200 gm./cm^2. and 550 gm./cm^2. for lead and iron respectively. The ratio of these two values was equal to the ratio of the gm./cm^2. of the first maxima for these materials. This might indicate that the same mechanism could account for the production of showers by this extremely penetrating producing radiation as by the softer producing radiation.

Next a series of experiments, using two counter outfits running simultaneously, was made at Hickory, N. C. (elev. 1100 ft.). This gave a set of data showing the double, triple, and quadruple coincidences at various thicknesses of producing material. The quadruple maximum was

at a greater thickness than the triple or double maxima and there was a general symmetry between the three sets of curves obtained. This seems to be in further agreement with the multiplication theory of showers.

With a set of counters arranged to count doubles and 274.17 gm./cm². of lead above various thicknesses of iron a set of data was obtained. This gave an initial drop and then a rise to saturation with the iron curve as run at Hickory. This behavior may be explained by assuming a longer mean free path for radiation in iron. The rise to the iron curve is due possibly to the production of new shower producing radiation in the iron. All this evidence seems to be in agreement with the recently developed multiplication theory of showers.

Plastic Give and Recovery in Stretched Neoprene. MILTON L. BRAUN.

A band in the shape of a closed hairpin 7 cm. long, cut from a 2 mm. slab of vulcanized neoprene, was subjected to a constant tension of slightly more than a kilogram, or of 1.20×10^7 dynes per square centimeter of original cross section, in a chamber having controlled temperature in the range between 16 and 50 degrees Centigrade. The rate of change in length with change in temperature varied between -0.010 to -0.028 cm. per degree for nearly a year. A steady rate was found to give way to a very sudden increase in length when a certain temperature was attained. This was interpreted as a plastic give. Recovery from the plastic give was established on the new plane of length upon reduction of temperature, but the recovered temperature rate of change in length was always numerically greater than that before the give. These plastic excursions occurred at increasingly elevated temperatures. The duration of the stretch, the time of maintenance of a selected temperature, and the rate of change of temperature are factors which have not as yet been correlated with the plastic give or recovery. The specimen of neoprene was supplied through courtesy of the Rubber Laboratory of the E. I. DuPont de Nemours and Company, Incorporated.

H. L. BLOMQUIST, *Secretary.*

PROCEEDINGS OF THE ELISHA MITCHELL SCIENTIFIC SOCIETY

October 13, 1936, to May 11, 1937

370th Meeting, October 13, 1936

M. J. Rosenau: *Epidemics of Influenza.*

A brief account of the history of influenza and its devastating pandemics which sweep the world at irregular intervals, about a generation apart. The mystery of the disease and recent advances concerning the discovery of its cause in the shape of a filterable virus. The modes of transmission, period of incubation, and other salient factors concerning the disease were given. Experiments with the disease on Cape Cod in the two towns of Brewster and Chatham were related and experiments during the great pandemics of 1917 and 1918 on the cause and mode of transmission of the disease were described.

371st Meeting, November 10, 1936

S. E. Smith: *Permeabilities of Cellulosic Films.*

The term "cellulosic films" includes films of regenerated cellulose and films of cellulose derivatives. The common property of the cellulose type "molecules" is vast length, relative to the other dimensions. Lateral attraction between these long chains results in the coherence of cellulose structures.

Cellulose films are hygroscopic. The moisture content is of prime importance to the condition of the film. The phenomena of swelling are well known among cellulose structures. The moisture content is also the determining factor in the permeability to gases. Dry cellulose films are completely impermeable to the permanent gases, while the permeabilities of moist films are in the ratio of the water solubilities of the diffusing gases.

T. F. Hickerson: *Secondary Stresses in Bridge Trusses.*

When a bridge truss is subjected to primary axial stresses due to loads applied at the joints, the tension members become slightly longer, and the compression members correspondingly shorter. The

angles formed by the members meeting at a joint therefore tend to increase or decrease. This angular change may take place freely in the pin-connected truss without restraint, but if the truss members are rigidly connected at the joints due to riveting or welding, bending will be induced. The stresses resulting from this bending are called Secondary Stresses. They are greatest near the ends of the members.

The following steps indicate the general procedure in the proposed method for computing Secondary Stresses:

(1) Knowing the deformations in each member of the truss due to the primary axial stresses (obtained by dividing the products of the unit stresses times the length by the modulus of elasticity (E)), determine the displacements of the joints from a Williot diagram; or preferably, determine the rotations of the members from the computed angle changes of the truss triangles as though they were pin-connected.

(2) Determine the relative displacements (d/L-values) of the ends of each member from Step 1, with plus sign for clockwise rotation and minus sign for counter-clockwise rotation.

(3) Calculate each joint rotation (θ) from the formula:

$$\theta = \frac{3\Sigma K \frac{d}{L}}{2\Sigma K} \tag{1}$$

in which

$$K = \frac{I}{L} = \frac{\text{Moment of inertia}}{\text{Length of member}}$$

(4) Letting the letters N and F refer to the "near" and "far" ends of the members, calculate each joint rotation (θ_N) by successive approximations; the first value is given by Eq. (1), and the other values are those brought over from the adjacent joints, the carry-over factor along any member being $-\frac{K}{2\Sigma K}$. Thus:

$$\theta_N = \frac{3\Sigma K \frac{d}{L}}{2\Sigma K} - \frac{\Sigma K \theta_F}{2\Sigma K} \tag{2}$$

(5) Compute the desired bending moments by means of the Slope-Deflection formula,

$$M_{NF} = 2EK\left(2\theta_N + \theta_F - 3E\frac{d}{L}\right) \tag{3}$$

from which the stresses follow directly.

372ND MEETING, DECEMBER 8, 1936

E. A. CAMERON: *On Loci Associated with Certain Osculants of a Plane Curve.*

Some geometric relations existing among certain osculants to a plane curve at a point were discussed. A study was made of the loci determined by these osculants as the point of contact is allowed to move along the base curve. Specialization of the base curve led to some interesting results.

J. F. DASHIELL: *The Experimental Background of the Gestalt Movement in Psychology.*

A few of the pioneer experiments leading to the development of the Gestalt school of psychological theory are described in simplified form. They are the phenomenon of apparent-movement (Wertheimer), the choosing of grays by hens, apes, and children (Köhler), the insightful learning of apes (Köhler). Other illustrations are incidentally introduced to clarify the Gestalt emphasis throughout upon wholeness as opposed to atomism in any field of psychology.

373RD MEETING, JANUARY 12, 1937

D. P. COSTELLO: *Notes on the Breeding Habits of Some Pacific Coast Nudibranchs.*

The nudibranchs are a group of marine gastropod molluscs characterized chiefly by the absence of a shell. In common with most gastropods, nudibranchs are hermaphroditic, and the animals, by pairs, practise reciprocal fertilization. Two to twenty-one days after mating, each member of the pair deposits a ribbon-like egg mass of fertilized eggs. The eggs are enclosed in capsules arranged in transverse rows across the ribbon, cemented together by a gel, and the ribbon is attached by one edge to the substratum in the form of a spiral of Archimedes. The egg ribbons of twenty species were studied and in all cases it was found that the spirals of Archimedes had been deposited in a counterclockwise direction (viewed dorsally).

OTTO STUHLMAN: *The Bio-Physics of the Human Ear.*

Published in the Jour. Amer. Acous. Soc. **9**: 119. 1937.

374TH MEETING, FEBRUARY 2, 1937

EDWARD MACK, JR.: *Why Rubber Stretches.*

An attempt at a theory of the mechanism of elastic stretching in rubber was made. The explanation was given in terms (1) of the free

rotation of carbon atoms about single bonds, and (2) of the attraction between hydrogen atoms of the hydrocarbon molecules. Some of the more important properties of the various forms of rubber were discussed from the point of view of strict adherence to the principles of geometry and of structural organic chemistry. Among the topics discussed were: shape of the rubber molecule, the work of stretching rubber, the shape of the stress-strain curve, heat effects in rubber, and properties of synthetic rubbers.

375TH MEETING, MARCH 2, 1937

H. WARD FERRILL: *The Adrenals and Experimental Diabetes.*

To be published in full in Archiv. of Int. Med.

The etiology and course of diabetes mellitus has been associated with adrenal function by various authors, since Zuelzer (1907) proposed that a mutual antagonism exists between the adrenals and pancreas. Due to the disagreement among workers and due to the fact that the supposed relationship of the two glands has in recent times led to surgical procedures, this problem was undertaken and carried out on a suitably large number of animals to be of significance.

The report is concerned chiefly with experiments to determine whether reduction or suppression of epinephrine secretion from the adrenal glands exerts a significant influence on experimental diabetes. In these experiments the criterion was the amount of insulin required to maintain the level of sugar excretion in the urine below about five grams daily and the concentration of sugar in the urine below about one per cent. The experiments were performed on dogs.

All the experimental and control animals were kept under identical or comparable conditions, on a constant diet consisting of 500 grams of boiled beef lung and 100 grams of cane sugar daily, divided into two meals. In the morning meal 50 grams of fresh raw beef pancreas was added. Drinking water was available at all times. Daily administration of insulin was divided into two doses and given at the time of feeding. Urine was collected for 24 hours, the quantity excreted and the sugar content determined at the same hour each morning.

Interference with epinephrine secretion was accomplished by excision of one adrenal and denervation of the other gland. In addition to denervation, the medulla of the remaining gland was curetted by drilling with a dental burr, so that most of the medulla was destroyed or damaged. The adrenal operations in these animals were performed in two stages and pancreatectomy was performed during the interval between

the adrenal operations. Other dogs were depancreatized without subjecting the adrenals to operations for reducing the epinephrine secretion. These served as controls. At the end of different periods of observation the experiment was terminated and the animals sacrificed for quantitative determination of the degree of reduction or suppression of epinephrine secretion by the method employed by Stewart and Rogoff.

From this series of experiments it has been concluded that:

1. The supposed dependence of experimental pancreatic diabetes on epinephrine secretion from the adrenals is not supported by substantial experimental evidence.
2. Severity of diabetes in depancreatized dogs is not modified by reduction or suppression of epinephrine secretion from the adrenals.
3. Insulin requirement on a constant diet is within the same range in depancreatized dogs and in dogs with reduced or suppressed epinephrine secretion in addition to pancreatectomy.
4. Depancreatized dogs with reduced or suppressed epinephrine secretion are not more sensitive to insulin than ordinary depancreatized dogs.
5. Depancreatized dogs kept for some weeks on a constant diet with adequate amounts of insulin to control glycosuria sooner or later show a reduction or suppression of epinephrine output from the adrenals.
6. Results obtained on depancreatized animals that have been subjected to operations on the adrenals should be interpreted with extreme caution unless the animals are obviously in excellent physical condition.

W. C. GEORGE: *The Significance of Blood in the Classification of Animals.*

The cytological details of blood cells sometimes afford taxonomic details that may be of significant help in cases difficult of classification. In the ascidians there are certain features of blood histology that appear to be familial in distribution, others generic, and still others specific. For example, certain peculiar cells, called colorless morula cells, are present in all species of the family Ascidiidae studied; they are not known to occur in representatives of any other family. They have distinct features for the different species and subspecies known to the author. The genus Ecteinascidia appears to be distinguished, furthermore, from all other ascidians by the presence of fusiform granules in

the orange cells. These granules of orange pigment have characteristic size variations in the different species. The two genera of the family Botryllidae are distinguished from one another by the presence of pigmented cells characteristic of each. In addition to the colored cells common to both genera, the genus Botryllus has cells with dark blue pigment and the genus Botrylloides has cells with brownish red pigment.

376TH MEETING, APRIL 6, 1937

E. W. MCCHESNEY: *The Identification of the Amino Acids.*
Published in full in Jour. Amer. Chem. Soc. **59:** 1116, 1937.

T. F. HICKERSON: *Multi-Storied Building Frames.*

Using the Slope-Deflection equations for an exact solution of multi-storied frames involves the determination of the rotation of every joint and the sidesway of every story. Accordingly, one is confronted with as many equations, to be solved simultaneously, as there are joints and stories in the framework, unless the bent is symmetrical about a vertical center line, in which case the number of unknown rotations are reduced fifty per cent.

The formal algebraic solution becomes exceedingly laborious and time consuming when the number of equations exceeds three or four and therefore the so-called exact method is not accepted as a satisfactory office method.

Whatever procedure is adopted, an important equation of Statics is the following: "Total Shear in any Story, times Story Height, equals the sum of the Moments at the top and bottom of all the Columns of that Story."

Useful formulas will now be derived on the basis of (1) $\Sigma M = 0$ at a joint and (2) $\Sigma M = 0$ in a story. Let joint N of a building frame subjected to a horizontal sidesway (d) represent the "near" end of any four members having I/L − values of K, K_1, K_2, and K_3; and with corresponding "far" ends at joints F, F_1, F_2, and F_3.

Since the members at joint N are in equilibrium under sidesway, we may apply $\Sigma M = 0$ at the joint. Then substituting in the Slope-Deflection equations, noting that each member rotates through the same angle (θ_N) at N, grouping terms, and solving, we have

$$\theta_N = \frac{3\Sigma K \frac{d}{h} - \Sigma K \theta_F}{2\Sigma K} \qquad (1)$$

Dividing Eq. (1) in two parts, multiplying by E, and letting

$$x = E\frac{d}{h}$$

we have:

$$E\theta_N = \frac{3\Sigma Kx}{2\Sigma K} - \frac{\Sigma KE\theta_F}{2\Sigma K} \tag{2}$$

The first part of Eq. (2) is the total rotation at any joint (N) caused by the sidesway of the adjacent upper and lower stories as if the other ends were fixed; while the second part is the sum of the rotations brought over from the far ends of all the members meeting at joint N. It should be noted that the carry-over factor along any member is $-\frac{K}{2\Sigma K}$.

Assuming the rotation at the far ends equal, and the *same* as that at the near end (that is $\theta_F = \theta_N$); then Eq. (2) takes the form:

$$E\theta_N = \frac{\Sigma Kx}{\Sigma K} \tag{3}$$

If one member meeting at a joint is known to have its far end fixed, as at each of the upper joints of the first story of a frame fixed at the bottom, then Eq. (3) would be modified slightly, for these special cases.

(2) Let K, K′, etc. $= \frac{L}{L}$ — values of the columns in any story;

θ_U, θ_L, etc. = corresponding rotations at the upper and lower joints respectively;

d = sidesway of any story; that is, the sideswise deflection of upper floor relative to the lower;

$x = E\frac{d}{h}$ = sidesway quantity for that story;

M = story moment (but if frame is symmetrical about a vertical center line, M = one-half "total shear in story" times "story height", and only one-half of the columns are considered); and $m = \frac{1}{6}M$.

If A, B, etc. are the columns in the story, we have:
for Column A,

$$M_U = 2\,EK\left(2\theta_U + \theta_L - 3\frac{d}{h}\right)$$

and

$$M_L = 2\,EK\left(2\theta_L + \theta_U - 3\frac{d}{h}\right)$$

for Column B,

$$M'_U = 2\,EK'\left(2\theta'_U + \theta'_L - 3\frac{d}{h}\right)$$

and

$$M'_L = 2\,EK'\left(2\theta'_L + \theta'_U - 3\frac{d}{h}\right); \text{ etc.}$$

Adding the foregoing expressions, and applying $\Sigma M = 0$ to the columns in the story, we have

$$6K(E\theta_U + E\theta_L) + 6K'(E\theta'_U + E\theta'_L) - \left(6E\frac{d}{h}\right)[2(K + K' + \ldots)] + M = 0$$

from which

$$x = E\frac{d}{h} = \frac{m + \Sigma K(E\theta_U + E\theta_L)}{2\,\Sigma K} \qquad (4)$$

In order to avoid possible confusion, it should be seen that Eqs. (1)-(3) include the K's of the members meeting at a joint; while Eq. (4) refers only to the K's of the columns in any story.

Label the joints and stories in consecutive order from the bottom upwards. Thus, let x_1 equal the sidesway quantity in the first story, x_2 equal that in the second story, etc.

The following steps are to be taken in carrying out the proposed method of analysis.

(1) Use Eq. (3) for finding the joint rotations in terms of the x's of the adjacent stories; set down the results in tabular form.

(2) Carry over the rotations from the far ends to the near end, using the factor $-\frac{K}{2\Sigma K}$.

(3) Apply Eq. (4) to each story and solve for x.

Note: Assuming as a first approximation, all the x's above any given story to be equal, not more than two equations need be solved simultaneously at a time even for multi-storied frames.

(4) Knowing x for each story the joint rotations can be found by successive approximations and finally the desired bending moments can be calculated from the formula,

$$M_{NF} = -2K(3x - 2\theta_N - \theta_F) \qquad (5)$$

As a final check on the calculations, the girder moments at a joint should equal the sum of the column moments at that joint.

377TH MEETING, MAY 11, 1937

R. F. POOLE: *Progress in the Control of Plant Diseases.*

The cryptogamic botanist and mycologist first conceived the possibilities of controlling organisms that cause plant diseases. Since the beginning of the Land Grant Colleges the plant pathologist has contributed much to the practical development of quality products and an economic agriculture. Plant pathology aims specifically toward economic and quality production rather than toward quantity production. The measures used for the control of plant diseases were discussed under six headings; namely, (1) Resistant varieties, (2) Rotation of crops, (3) Soil treatment, (4) Adaptability, (5) Sanitary practices, and (6) Chemical treatments. Important advancements in technique, in the perfection of chemical formula and application, the behavior of organisms in changed soil media and the destruction of inoculum were discussed. The lecture was illustrated, demonstrating the serious losses caused by plant diseases and the effects of practical control measures.

The following officers were elected for the year 1937–1938:

President—John N. Couch.

Vice-President—H. D. Crockford.

Secretary-Treasurer—E. L. Mackie.

The permanent secretary, E. T. Browne, and the editors of the Journal, W. C. Coker, Otto Stuhlman, and C. D. Beers, the last-named having been elected at the December meeting to fill the vacancy caused by the resignation of Dr. H. V. Wilson, were continued in office.

A CLASSIC PROBLEM IN EUCLIDEAN GEOMETRY

A Basic Study*

By Archibald Henderson

I

For approximately a century the harmless-looking exercise in Euclidean geometry, studied in the present monograph, has attracted from mathematicians a measure of attention apparently disproportionate to its importance. Among the many who have attacked it may be mentioned Todhunter, Sylvester, Greenstreet, Lemoine, Meurice, Tarry, Lanvernay, Halsted, Birkhoff, and Hopkins. Numerous solutions, some authentic but many the reverse, have been published in England and the United States and on the continent of Europe. It is not a little singular that the published "solutions" are, in a surprising number of cases, incomplete, inadequate, incorrect, and even grossly and ludicrously erroneous.[1]

Despite the appreciable number of isolated "solutions" which have, often incautiously, been submitted to public scrutiny, no thoroughgoing analysis of the problem has ever been made. It is primarily on this account that I have ventured upon this diverting excursion and pleasure trip. Indeed I may wellnigh venture to describe this paper as an essay on the internal bisector problem to end all essays on the internal bisector problem. In 1900 one G. D. Birkhoff, then unknown to

* This study is dedicated to George D. Birkhoff, President of the American Association for the Advancement of Science. *Cf. infra.*

[1] For example, the solution proposed by the Rev. William Mason and endorsed by T. T. Wilkinson is unsound, as is also the discussion by the latter. See *The Lady's and Gentleman's Diary*, No. 156, pp. 87–8 (1859), and No. 157, pp. 84–86 (1860). It seems incredible that the erroneous "solution," submitted by F. G. Hesse, should ever have been recommended by J. J. Sylvester and N. M. Ferrers as "thoroughly sound" and actually published in the *Philosophical Magazine*, 4th ser. **47**: 354–6 (1874). Nine different purported solutions appeared in the *American Mathematical Monthly* **2**: 157–8, 189–92; **5**: 108–9; **7**: 226–8; but the mortality was devastating. Only two of the solutions were free from flaws, one of those being indirect, the other by trigonometry. Even the "solution" by the editor, admittedly "adapted" from a solution by the editor of the mathematical department of *The Educational Times*, is unsound.

fame, submitted to the editor of the *American Mathematical Monthly* a solution of the proposed "teaser," a solution which was not published, Birkhoff's name being included in the list of "others who submitted solutions." As almost all the published "solutions" were absurdly erroneous, the editor might perhaps better have taken a chance on publishing Birkhoff's solution, now irrevocably lost, than those he was so injudicious as to print, including his own erroneously "adapted" one. A certain piquancy attaches to the task of making an exhaustive study of this problem and its history. It is like breaking a butterfly on a wheel. And yet—the Biblical parable of the grain of mustard seed or the familiar rhyme about the little acorn finds convincing exemplification here. Felix Klein wrote delightfully and searchingly of three famous geometrical classics of antiquity: the squaring of the circle, the duplication of the cube, and the trisection of the angle. David Hilbert delivered some charming lectures on the foundations of geometry. Einstein and Birkhoff divided honors over the mathematical recreation of the impact of two billiard balls according to the mechanics of special relativity. With such stimulating examples of recreational relaxation before me, I see no bar to vying with them in the field of mathematical diversion, and by searching analysis magnifying an innocent-looking geometrical exercise into a classic of modernity.

II

In the course of these researches, which have led me to many new proofs, I have discovered that this little exercise, shy and shrinking as the modest violet, has wide ramifications of surprising interest and variety. Invoked for its proof are principles of continuity, symmetry, inversion, reciprocation, antiparallels, cross ratio, harmonic ranges and pencils, the complete quadrangle, the question of constructibility by means of ruler and compasses. The exercise seems to stand on the border-line between metrical and projective geometry, between Euclidean and non-Euclidean geometry, sharing alike the adventitious yet highly effective aid of analytic geometry and higher plane curves. We need not be surprised to discover that the exercise is a special case, one of an infinite number of similar special cases, of a theorem of a more general nature. Study of this more general theorem enables us to view the whole problem in a new perspective, giving rise as it does to provocative questions regarding other interesting features of, and configurations associated with, the triangle.

It is passing strange that this problem, so far as I have been able to

discover, received no consideration or even mention by geometers, ancient or modern, in either direct or converse form, until about a century ago. Four issues are involved: (a) to find new direct proofs by theorems in the books which succeed Book I of Euclidean geometry as we have it today; (b) to find new indirect proofs; (c) to find that which not a few mathematicians have failed to find, direct proofs by the use of theorems in Book I only; and (d) to clear up the obscurity and mystery concerning the problem's exaggerated yet unmistakably cryptic difficulties.

These difficulties are all the more surprising in view of the fact that the problem under consideration is the converse of an exercise in Book I, the proof of which offers no difficulties whatever.[2] The study of the converse of this almost trivial exercise has thrown into sharp relief several theorems, commonly slighted or wholly ignored in works on geometry ancient or modern, which are nevertheless of genuine interest and fundamental importance. The present treatment of the internal bisector problem, with its many implications and ramifications, may perhaps furnish fresh information and new points of view, even to the trained mathematician.

III

In a French journal,[3] just ninety-five years ago, was proposed, for the first time so far as is at present known, the following problem under the caption "Théorèmes à Demonstrer.—Problèmes":

THEOREM 1. *To demonstrate that if in a rectilinear triangle two interior angular bisectors are of equal length, the triangle is isosceles.*

This is the converse of the very easy exercise: "The internal bisectors

[2] The writers of textbooks in geometry almost invariably omit the problem of this paper. Considerable space with adequate references, however, is accorded it in J. S. Mackay's *Euclid*; and a solution by Descube is given in Mackay's *A Key to Euclid*. The exercise is assigned in George C. Edwards's *Elements of Geometry* (1896), being included among the miscellaneous exercises on page 138. In G. A. Wentworth's *Plane Geometry* (revised edition, 1899), p. 72, the converse of our problem is assigned and its "opposite" is solved in the text; but the pupil is asked, not to solve, but merely to state, our problem and to tell whether it is true. In the same author's *Exercises in Wentworth's Geometry* (revised edition, 1880), p. 10, the converse of our problem is proved; but our problem and its opposite are merely stated without comment. No reference to this problem, rather surprisingly, is found in Julius Peterson's *Methods and Theories for the Solution of Problems of Geometrical Construction* (English translation, 1923), a work almost more difficult to read in the weird translation than in the original Danish (1866).

[3] Nouvelles Annales de Mathématiques **2**: 57 (1842).

of the base angles of an isosceles triangle, terminating in the sides including the third angle, are equal." Soon after the appearance of the problem to be solved, two solutions appeared in the same journal of the same year, one of them indirect and each using theorems of Books II and III, in particular the same somewhat unfamiliar theorem which is fundamental in the theory of inversion.[4]

It was not until almost ten years later that the problem appears to have piqued the interest of mathematicians of the University of Cambridge, where, as Sylvester observes, "it excited considerable attention among the mathematicians of the place." Certainly Isaac Todhunter did not shine in this affair, as he failed to obtain a direct solution; and Sylvester also betrayed himself as surprisingly inept in his approach to the entire problem. In the first paper which appeared in English on the subject, Sylvester, then of the Royal Military Academy, Woolwich, erroneously conceived the notion that the problem was incapable of direct demonstration. He ventured to indulge in the following bantering comment, presumably aimed at Dr. Isaac Todhunter of Cambridge:

> If report may be believed, intellectuals capable of extending the bounds of the planetary system and lighting up new regions of the universe with the torch of analysis, have been baffled by the difficulties of the elementary problem stated at the outset of this paper, in consequence, it is to be presumed, of seeking a form of geometrical demonstration of which the question from its nature does not admit. If this be so, no better evidence could be desired to evince the importance of such a criterion as that suggested in the text.[5]

The criterion suggested is thus stated by Sylvester: "Whenever the truth of a geometrical theorem depends on the necessary non-existence of real roots (between prescribed limits) of the analytical equation ex-

[4] Solution by M. Rougevin, "élève de la classe de Mathématiques élémentaires du Collège Louis-le-Grand [Institution Lorial]", *ibid.*, **1**: 138–9; and solution by Mr. Grout de Saint-Paer, "élève du Collège de Versailles," i, 311. The solution by T. T. Wilkinson, F. R. A. S. in *The Lady's and Gentleman's Diary*, No. 154, pp. 58–9 (1856) is virtually identical with that of Rougevin and presumably based upon it.

[5] On a Simple Geometrical Problem illustrating a Conjectured Principle in the Theory of Geometrical Method. *Philosophical Magazine* **4**: 366–9 (1852). The same article is found in Sylvester's *Collected Works* **1**: 392–5 (1837–1853). One may observe that no better evidence than this could be desired, that the difficulties which Todhunter, Sylvester, and other English mathematicians could not overcome, in the effort to find a direct demonstration of the problem, were very real difficulties indeed.

pressing the conditions of the question, no other form of proof than that of the *reductio ad absurdum* is possible in the nature of things." This criterion was advanced by Sylvester because he was unable to devise a direct proof of a theorem upon which the bisector problem may be shown immediately to depend, namely:

THEOREM 2. *If from the middle of a circular arc two chords of the circle be drawn, the remoter segments of the two chords cut off by the chord of the given arc being equal, then the nearer segments will also be equal.*

Referring to this theorem, Sylvester says: "As an example, I throw out (not a challenge, but) an invitation to discover a direct proof, if such exist, of the following geometrical theorem, as simple a one as it is perhaps possible to imagine. . . ."[6]

IV

As Theorem 2 is of some intrinsic interest as well as the basis of several proofs of the bisector problem, I present below a simple proof unlike others I have seen. The theorem is one of a group of associated theorems, all capable of similar direct demonstrations. Taken together they constitute the fundamental principle of the theory of inversion.

Given N the mid-point of circular arc BNC; and NK_1A_1, NK_2A_2 two chords, with $K_1A_1 = K_2A_2$ (Fig. 1). From N drop a perpendicular NM on chord BC, meeting the circle again in L; and let the chord LA_1 produced meet BC produced in D. Join N, A_1, A_2 by chords to B and C. From the pairs of congruent triangles MNK_1, A_1NL and MNK_2, A_2NL, we have

$$NL \cdot NM = NK_1 \cdot NA_1 = NK_2 \cdot NA_2 \ldots\ldots\ldots\ldots \quad (1)$$

Hence

$$NK_1(NK_1 + K_1A_1) = NK_2(NK_2 + K_2A_2)$$

giving $NK_1 = NK_2$, since $K_1A_1 = K_2A_2$ by hypothesis. We may note, therefore, that $MK_1 = MK_2$ and $\angle A_1K_1C = \angle A_2K_2B$. Moreover,

[6] This invitation evoked a reply, in three parts, by James Adamson, D.D., which while very diffuse contains a satisfactory answer to Sylvester's query, together with a refutation of his unsound criterion: "On a proposed Test of the Necessity of Indirect Proof of Geometrical Demonstrations, with Remarks on Methods of Demonstration." *Philosophical Magazine* **1**: 297–9, 332–8, 405–410 (1853). Other, chiefly brief, contributions to the subject appeared in *The Educational Times*, 1853 *et seq., passim*. An extremely lengthy and complicated proof of the bisector problem, by means of reciprocation and the use of the external bisectors, is that of T. K. Abbott, *Philosophical Magazine* **5**: 286–7 (1853).

from the pairs of similar triangles MNB, MBL and MNC, NCL, we have

$$\overline{NB}^2 = \overline{NC}^2 = NL \cdot NM \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Hence from (1) and (2),

$$\overline{NB}^2 = \overline{NC}^2 = NK_1 \cdot NA_1 = NK_2 \cdot NA_2$$

which is the fundamental equation of inversion $\rho\rho' = a^2$. Furthermore, A_1N, A_2N are the internal bisectors of angles BA_1C, BA_2C, since

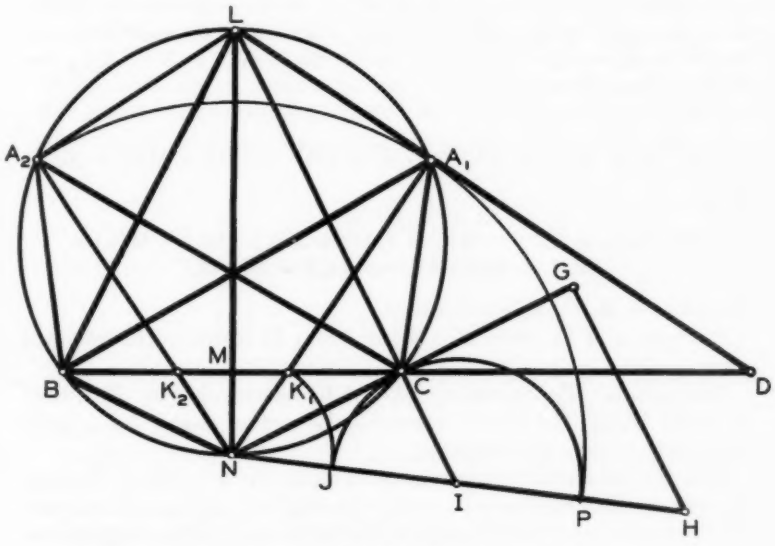

FIG. 1

each of the four angles BA_1N, CA_1N, BA_2N, CA_2N is measured by one-fourth the arc BNC. Since this is also the case with angles BCN, CBN, we may also derive equation (3) by comparison of the two pairs of similar triangles NK_1C, NCA_1 and NK_2B, NBA_2. We should also note that LD is the external bisector of $\angle BA_1C$ since LA_1 is perpendicular to NA_1, and that B, K_1, C, D form a harmonic range, giving the proportions $BK_1:K_1C::K_2C:BK_2::A_1B:A_1C::A_2C:A_2B::BD:DC$.

Since from equation (1), if $NK_1 = NK_2$, we have $NA_1 = NA_2$ and

$K_1A_1 = K_2A_2$; and since if $NA_1 = NA_2$, we have $NK_1 = NK_2$ and $K_1A_1 = K_2A_2$, we may formulate two more theorems:

THEOREM 3. *If from the middle of a circular arc two chords of the circle be drawn, the nearer segments of the two chords cut off by the given arc being equal, the remoter segments will also be equal.*

THEOREM 4. *If from the middle of a circular arc two equal chords of the circle be drawn, the nearer and the remoter segments of the two chords cut off by the chord of the given arc will be equal, each to each.*

By a similar argument we may readily demonstrate the following theorem:

THEOREM 5. *If, from a fixed point (N) on the perpendicular bisector (NL) of a given segment (BC), a line be drawn within the angle CNL cutting BC at K_1 and determining A_1 from the relation $\overline{NC}^2 = NK_1 \cdot NA_1$, then B, N, C, A_1 are concyclic.*

Thus

$$NK_1(NK_1 + K_1A_1) = \overline{NC}^2 = \overline{NM}^2 + \overline{MC}^2 = \overline{NK_1}^2 - \overline{MK_1}^2 + \overline{MC}^2$$

Hence

$$NK_1 \cdot K_1A_1 = \overline{MC}^2 - \overline{MK_1}^2 = (MC + MK_1) \cdot (MC - MK_1) = (BM + MK_1)(MC - MK_1) = BK_1 \cdot K_1C$$

Therefore B, N, C, A_1 are concyclic.

The results of Theorems 2, 3, 4 and 5 may be stated in the following form:

THEOREM 6. *Two triangles (A_1BC, A_2BC) having the base (BC), vertical angle (BA_1C, CA_2B) and bisector of the vertical angle (A_1K_1, A_2K_2) equal, each to each, are congruent.*

This follows directly from symmetry about the line NML. It is extraordinary that this basic theorem regarding two triangles is conspicuous by its absence from virtually all text books and treatises on geometry in any language. If one triangle A_1BC is in position, the other may immediately be constructed by determining A_2 as the intersection of the circle through A_1, C, N, B with the circle of center N and radius NA_1. Theorem 6 may be stated as a problem in construction.

CONSTRUCTION 1. *To construct, on BC as a base and on the same side of BC, a triangle congruent to ΔA_1BC: find the intersection of the circumscribing circle of the ΔA_1BC and the circle of center N and radius NA, where N is the meet of the perpendicular bisector of BC with the circumcircle BCA_1. The point thus found (A_2) is the vertex of the required triangle A_2BC.*

We are now in a position to formulate two constructions for the following problem in construction: *Given the parts a, A, t_a of a triangle ABC; to construct the ΔABC.*

CONSTRUCTION 2. At C lay off below BC ($= a$) an angle equal to $\frac{1}{2}A$, the other leg cutting the perpendicular bisector of BC at M, in N (Fig. 1). Let the circumcircle of ΔBNC cut NM in L. If we imagine the required triangle drawn in the position A_1BC, we have

$$NK_1 \cdot (NK_1 + t_a) = \overline{NC}^2$$

giving

$$NK_1 = \tfrac{1}{2}(-t_a + \sqrt{(t_a)^2 + 4\overline{NC}^2})$$

This can readily be constructed by extending NC to G, making $CG = NC$, and erecting a perpendicular to NG at G, laying off on it $GH = t_a$. Join H to N, the line HN cutting the perpendicular to NG at C in I. Then

$$NI = \tfrac{1}{2}\sqrt{(t_a)^2 + 4\overline{NC}^2}$$

Laying off IJ toward N equal to $\frac{1}{2}t_a$, we have

$$NJ = \tfrac{1}{2}(-t_a + \sqrt{(t_a)^2 + 4\overline{NC}^2}) = NK_1$$

Hence with N as center and NJ as radius describe arc cutting BC at K_1. Then NK_1 extended cuts the circle BNC in the vertex (A_1) of the required triangle.

CONSTRUCTION 3. For NK_1 we may write $NA_1 - t_a$ and therefore $(NA_1 - t_a) \cdot NA_1 = NC$, giving

$$NA_1 = \tfrac{1}{2}(t_a + \sqrt{(t_a)^2 + 4\overline{NC}^2})$$

Lay off, on NI extended, $IP = IC$, giving

$$NP = \tfrac{1}{2}(t_a + \sqrt{(t_a) + 4\overline{NC}^2}) = NA_1$$

The circle with N as center and NP as radius will cut the circle BNC in the vertex (A_1) of the required triangle.

PROOF I. The bisector problem is immediately solved by means of Theorem 6. Given BE, CF the equal bisectors of the base angles B, C of ΔABC meeting in O (Fig. 2). Then AO is the bisector of $\angle A$, since

the internal bisectors of the three angles of a triangle are concurrent. Hence $\Delta ABE = \Delta ACF$, by Theorem 6, and therefore $AB = AC$.[7]

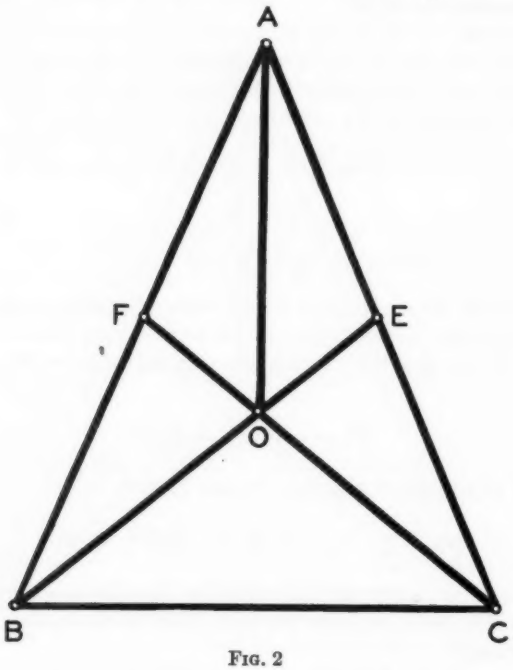

FIG. 2

V

In this section will be given seven new direct proofs of the bisector problem, based upon theorems in Books II and III. The first four of these proofs, succinct and elegant, are intimately connected.

PROOF II. Given ΔABC with AD internal bisector of $\angle BAC$ (Fig. 3). At C lay off from AC and in the same sense an angle equal to $\angle ADB$, the other side meeting AD produced in L. Hence

$$AB \cdot AC = AD \cdot AL = AD(AD + DL)$$

giving

$$\overline{AD}^2 = AB \cdot AC - AD \cdot DL \ldots\ldots\ldots\ldots\ldots (1)$$

[7] With a figure similar to Fig. 1, Rougevin, *l.c.*, gives an indirect proof, involving comparison of arcs, whereas the above proof is direct.

Since ΔCDL is similar to ΔADB,

$$AD \cdot DL = BD \cdot CD \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

From (1) and (2) we have

$$\overline{AD}^2 = AB \cdot AC - BD \cdot CD \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Now from the bisector property, we have

$$AB \cdot CD - AC \cdot BD = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

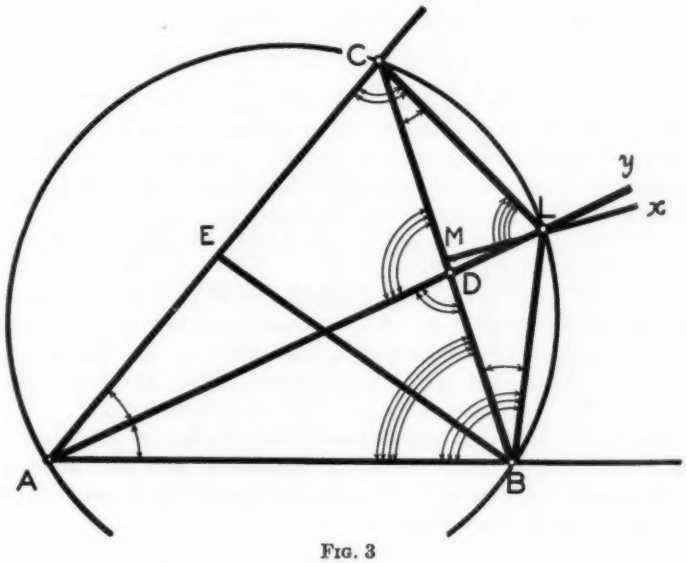

FIG. 3

Adding (4) to, and subtracting (4) from, (3), we have the familiar forms:

$$\overline{AD}^2 = (AC + CD)(AB - BD) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

and

$$\overline{AD}^2 = (AB + BD)(AC - CD) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

From (4) the right hand sides of equations (5) and (6), it may be noted, are equal, by composition and division:

$$AB + BD : AB - AD :: AC + CD : AC - CD \quad \ldots\ldots\ldots\ldots \quad (7)$$

The proof now follows at once. If BE is the internal bisector of $\angle$ ABC, we have, after the analogy of (5) or (6),

$$\overline{BE}^2 = (BC + CE)(AB - AE) \quad \ldots\ldots\ldots\ldots\ldots (8)$$

Hence if AD = BE, we have from (5) and (8),

$$\frac{BC + CE}{AC + CD} = \frac{AB - BD}{AB - AE} = \frac{AB - (BC - CD)}{AB - (AC - CE)} =$$

$$\frac{AB + CE + CD}{AB + CE + CD} = 1 \quad \ldots\ldots (9)$$

by combining first and third fractions. Hence

$$BC - CD = AC - CE \text{ or } BD = AE$$

Since $\Delta ABE = \Delta ABD$, $\angle BAC = \angle ABC$, giving BC = AC.[8]

PROOF III. We may also proceed as follows: From AB and in the same sense lay off an angle equal to $\angle$ ADC, the other side meeting AD produced in K say (not shown in Fig. 3, but identical with L). The remainder of the proof is precisely analogous to Proof II.

PROOF IV. Draw the circumcircle of ΔABC cutting AD produced at L. The proof follows as above.

PROOF V. Erect perpendicular bisector of BC, at its mid-point M, meeting AD produced at L. If circumcircle of ΔABC meets AD produced at K, then K coincides with L, since LB = LC and chord KB = chord KC. Then since ΔACL is similar to ΔADB, AD + DL:AC = AB:AD. The remainder of the proof follows as in Proof II.

PROOF VI. The next proof utilizes the principle of inversion and brings out a property discovered by Lanvernay and later arrived at independently by Meurice.[9] The construction of Fig. 4 was suggested by equation (6) in Proof II above:

$$\overline{AD}^2 = (AB + BD)(AC - CD)$$

A similar proof, with figure to correspond, may also be derived from equation (5), Proof II.

Given ΔABC and AD bisector of $\angle$ BAC (Fig. 4). Lay off from C

[8] A more lengthy and cumbersome treatment is that of W. E. Heal, *American Mathematical Monthly* **24:** 344–5.

[9] E. Lanvernay, *Mathesis* **14:** 40 (1894). In the same volume of the same journal, page 92, M. L. Meurice gives a proof of Lanvernay's Theorem by the use of an escribed circle.

toward A, CH = CD, and join H to D. Lay off on AB toward B, AG = AH; and from A drop a perpendicular AI upon DG extended to J, laying off IJ = DI. Let circle through D, A, J meet AB produced at K, and join K to D. Then

$$\overline{AD}^2 = AK \cdot AG \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

by the principle of inversion. Since also AG = AH and $\angle$ HAD = $\angle$ DAK, ΔAHD is similar to ΔADK and

$$\angle ADH = \angle AKD \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

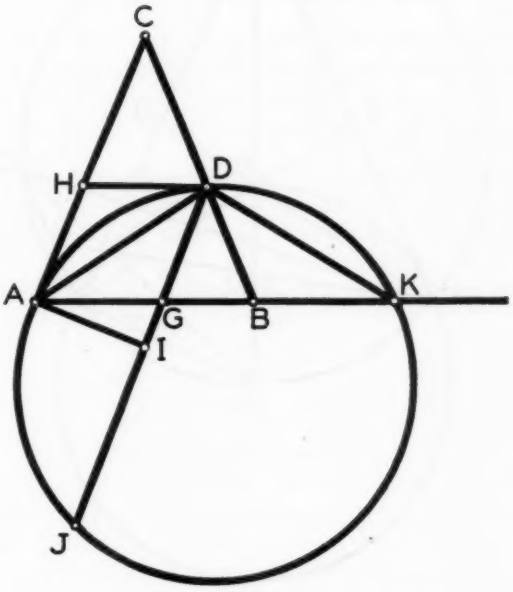

FIG. 4

Now $\angle$ DGK + $\angle$ GDB + $\angle$ BDK + $\angle$ AKD = 180° and $\angle$ CDH + $\angle$ ADH + $\angle$ ADG + $\angle$ GDB = 180°. Since $\angle$ CDH = $\angle$ CHD = $\angle$ DGK, and $\angle$ ADH = $\angle$ ADG = $\angle$ AKD by (2), we have $\angle$ BDK = $\angle$ ADG = $\angle$ ADH = $\angle$ AKD by (2) and

$$BD = BK \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Hence

$$\overline{AD}^2 = AK \cdot AH = (AB + BK)(AC - CH) = (AB + BD)(AC - CD)$$

The remainder of the proof follows as in Proof II.

PROOF VII. Given ΔABC_1, with $\angle AC_1B = \angle C$ (Fig. 5). The bisectors AD_1, BE_1 of the angles BAC_1, ABC_1 meet in the point P_1. Prolong $C_1P_1F_1$, to meet the perpendicular bisector of AB at M, in the point N; and draw the straight line BN. Now the circumcircle of the ΔABC_1

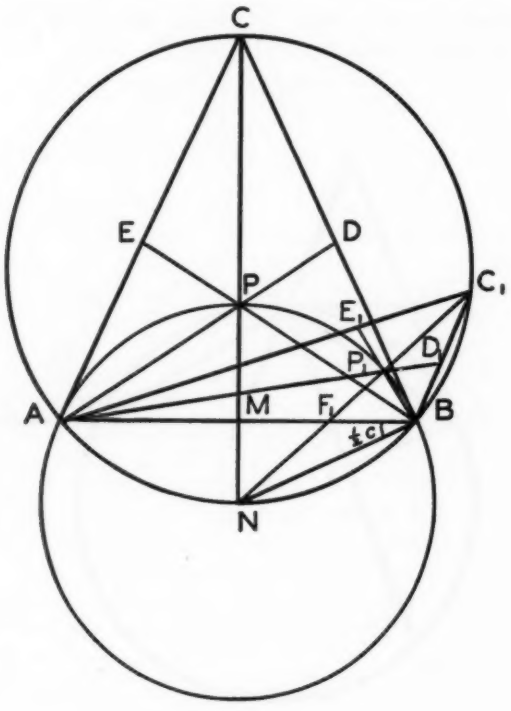

FIG. 5

passes through N, since CP_1 meets it in the mid-point of arc AB, which lies on the line MN. Hence

$$\angle ABN = \angle AC_1N = \tfrac{1}{2} \angle AC_1B = \tfrac{1}{2} \angle C$$

Now

$$\angle AP_1F_1 = \tfrac{1}{2} \angle BAC + \tfrac{1}{2} \angle AC_1B$$

and

$$\angle BP_1F_1 = \tfrac{1}{2} \angle ABC_1 + \tfrac{1}{2} \angle AC_1B$$

Therefore

$$\angle AP_1B = \tfrac{1}{2} \angle BAC_1 + \tfrac{1}{2} \angle ABC_1 + \angle AC_1B = 90° - \tfrac{1}{2} \angle AC_1B + \angle AC_1B = 90° + \tfrac{1}{2} \angle C$$

which is a constant angle. Now describe a circle with center N and radius NA = NB, cutting NM produced in P. Then

$$\angle NPB = \angle NBP = 45° + \tfrac{1}{4}C$$

since $\angle MNB = 90° - \frac{1}{2}C$. Prolong NMP to meet the circle through A, N, B, and C_1 in C; draw straight lines AC and BC, and prolong AP, BP to meet BC, AC in D, E respectively. Since $\angle AP_1B = \angle APB = 90° + \frac{1}{2}C$, P_1 describes the arc BP_1P as C_1 describes the arc BC_1C.

Let us now recall the theorem: "In every triangle ABC, to a greater side AC is drawn a smaller internal bisector BE" (For a proof of this theorem, *cf.* E. Catalan, *Théorèmes et Problèmes de Géometrie Élémentaire*, Theorem VIII (6th edition, revised and enlarged. Paris. Dunod. 1879).[10] As C_1 traverses arc from B to C, AC_1 is always greater than BC_1, since arc ACC_1 is greater than arc BC. Hence AD_1 for this interval is always greater than BE_1. Similarly, for the symmetrical arc AC, BE_1 remains greater than AD_1. When C_1 reaches C and P_1 reaches P, then D_1 reaches D and E_1 reaches E. Now AD, BE are the bisectors of the angles BAC, ABC respectively. But $\angle PAB = \angle PBA$, since AP = BP. Now $\Delta APE = \Delta BPD$, since AP = BP, $\angle APE = \angle BPE$, and $\angle PAE = \angle PBD$. Therefore PD = PE, and consequently AD = BE. Note that this is otherwise obvious, if we invoke the principle of continuity. Since C_1 is at C when P_1 is at P, AC = BC.

This is perhaps the most satisfying of all the proofs, since the internal bisector problem and its converse are both seen to be true, by the use of this figure.

PROOF VIII. Given ΔABC with equal internal bisectors BE, CF of base angles ABC, ACB (Fig. 6). Lay off $\angle CFx = \angle EBA(= \frac{1}{2} \angle B)$, and $\angle FCy = \angle BEA(= \frac{1}{2} \angle C)$, Fx and Cy meeting at A_1. Then $\Delta FCA_1 = \Delta BEA$. Hence the bisectors of $\angle FAC$ and $\angle FA_1C$

[10] This theorem immediately furnishes a solution of the internal bisector problem, by the indirect method.

meet at N, mid-point of arc FNC of circle passing through F, N, C, A_1, A. Let NA, NA_1 meet FC in K and K_1; then $AK = A_1K_1$, being corresponding parts of congruent triangles ABE and A_1FC. Now

$$\angle FCN = \angle CFN = \tfrac{1}{2} \angle FAC = \tfrac{1}{2} \angle FA_1C,$$

each being measured by one-half of arc FNC. Then NF, NC are tangents to circumcircles of ΔAKF, ΔA_1K_1C respectively, giving $\overline{NF}^2 = NK \cdot NA$ and $\overline{NC}^2 = NK_1 \cdot NA_1$. Hence $NA = NA_1$ and $NK = NK_1$, since $NF = NC$ and $KA = K_1A_1$. Then $\angle NAA_1 = \angle NA_1A$; and since $\angle NAC = \angle NA_1F$, we have $\angle CAA_1 = \angle FA_1A$. Conse-

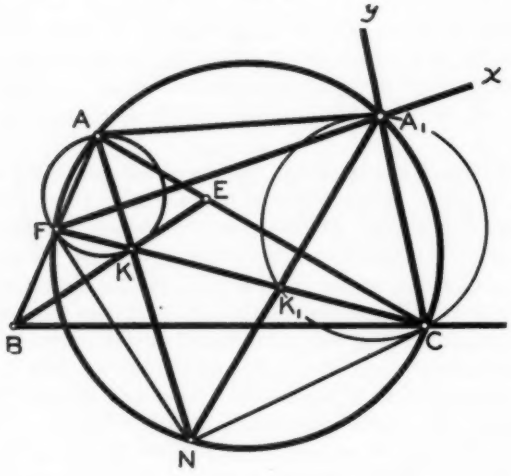

FIG. 6

quently arc AF = arc A_1C, and chord AF = chord A_1C = AE. Therefore $\Delta AFK = \Delta AEK$, and consequently $\Delta AEB = \Delta AFC$, giving AB = AC.

VI

A more intensive study of the bisector problem, from the standpoint of higher plane curves, may afford some deeper insight into the reasons why this innocent-seeming geometrical exercise presents peculiar difficulties. In the analysis is shown the organic relation of the bisector configuration to three well-known curves: the logarithmic spiral, the conchoid, and the cardioid.

(A) THE LOGARITHMIC SPIRAL

Given the ΔABC, with AD internal bisector of $\angle$ BAC (Fig. 7). Lay off on CA, CH = CD; on AB, AG = AH; and on AB produced,

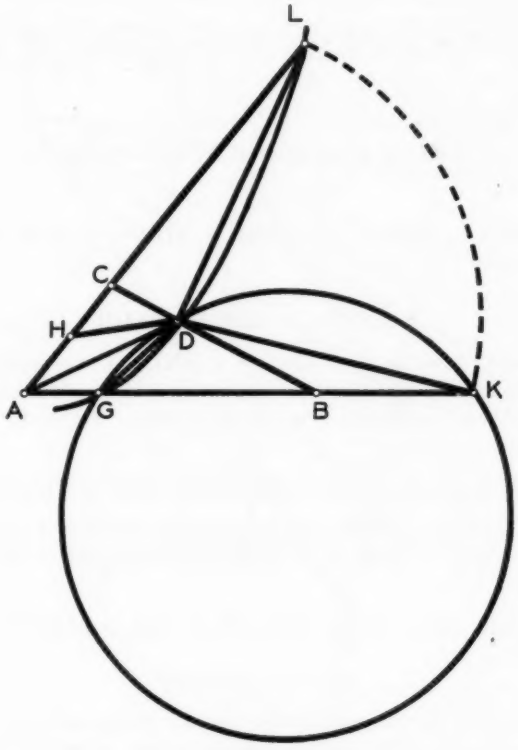

FIG. 7

BK = BD. Then describe an arc with D as center, DK as radius, cutting AC produced at L. Join D by straight lines to G, K, and L. Choose AG = AH = AC − CH = AC − CD as unit of measure. Through G and D draw the logarithmic spiral

$$\rho = (\mathrm{AD})^{\frac{2\theta}{\alpha}}$$

where $\angle\alpha = \angle$ BAC. If this spiral meets AC produced in L′ (not shown in Fig. 7), we have, since $\Theta = \alpha$, $\rho = (AD)^2 = AL'$. Then ΔAGD is similar to $\Delta ADL'$, since $\angle$ DAG = $\angle$ DAL′ and AL′:AD:: AD:AG (= 1).

Now

$$\angle \text{DAH} = 180° - \angle \text{AHD} - \angle \text{ADH} = \angle \text{DAB} = 180° - \angle \text{ADB} - \angle \text{BDK} - \angle \text{BKD}$$

giving

$$\angle \text{AHD} + \angle \text{ADH} = \angle \text{ADB} + 2 \angle \text{BKD} \ldots\ldots\ldots (1)$$

Moreover

$$\angle \text{CHD} + \angle \text{AHD} = \angle \text{CDH} + \angle \text{ADH} + \angle \text{ADB} = 180°$$

giving

$$\angle \text{AHD} - \angle \text{ADH} = \angle \text{ADB} \ldots\ldots\ldots\ldots (2)$$

From (1) and (2) we have $\angle$ ADH = $\angle$ BKD. Consequently ΔAHD is similar to ΔADK, and therefore similar to ΔADL. But since $\Delta AGD = \Delta AHD$, therefore ΔAGD is similar to ΔADL. Hence L′ falls at L; and we have

$$\overline{AD}^2 = AK = AK \cdot 1 = (AB + BK)(AG) = (AB + BD)(AC - CD)$$

Incidentally we may derive this property by means of the circumcircle of ΔGDK. Since $\angle$ ADG = $\angle$ ADK, AD is tangent to this circle at D, giving

$$\overline{AD}^2 = AK \cdot AG = (AB + BK)(AH) = (AB + BD)(AC - CD)$$

(B) THE CONCHOID

The relation of the conchoid to the bisector configuration is even more interesting than that of the logarithmic spiral. Consider the following construction:

(A) CONSTRUCTION. *Through a given point (P) to draw a line, of which the legs of a given angle ($\angle$ xAy) cut off a given length l (BC).*

Through the given point P draw a series of lines, laying off the given length *l* to the right of the vertical side Ax of the given $\angle$ xAy, given in position (Fig. 8). Then the locus of the extremities of these lines is a conchoid; and it meets Ay in the required point C, giving the required line PBC. In general, the construction (A) by ruler and compasses alone cannot be made, since it is impossible to satisfy simultaneously

the three conditions: (1) direction of transversal; (2) the falling of B on Ax; (3) the falling of C on Ay. For this purpose a graduated ruler is required.

(B) A SPECIAL CASE. It may happen, however, that the given point P occupy some particular position with reference to the conchoid and $\angle$ xAy, which will permit the construction in the special case to be effected by ruler and compasses. This enables us to effect Construction

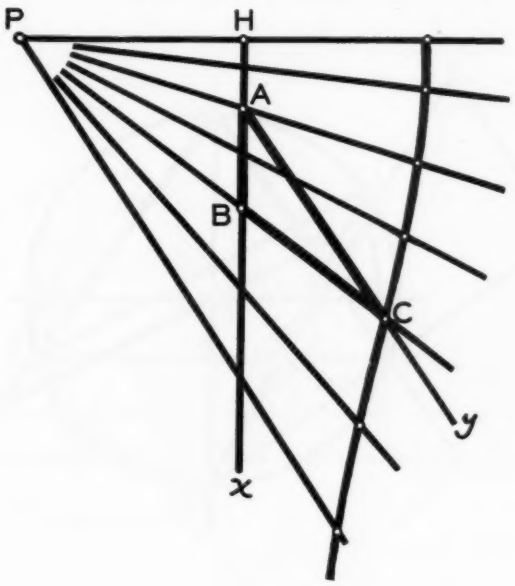

FIG. 8

2, Section IV above: *Given the parts a, A, t_a of a triangle ABC (not drawn), to construct the triangle.*

CONSTRUCTION 4. Take the point P on the bisector Az of the given $\angle$ xAy, with AP = t_a (Fig. 9). Erect a perpendicular to AP at P, and lay off, on either side of AP,

$$PQ = PR = {}^{a}/2 = l/2$$

where l is the given length of Construction (A). Through Q, R draw lines parallel to AP, meeting Ay, Ax in S, T respectively and join S to T. Draw circumcircle of ΔAST, this circle and ST cutting AP produced in

N, M respectively. If we assume the required line NKL in position, as bisector of $\angle$ SLT($= \angle$ A) in the triangle SLT, with TS = a and KL = AP = t_a, then

$$NK \cdot NL \equiv NK \cdot (NK + KL) = NK(NK + AP) = \overline{NT}^2$$

as given in Section IV, Construction 2. Then

$$NK = \tfrac{1}{2}(-t_a + \sqrt{(t_a)^2 + 4\,\overline{NT}^2})$$

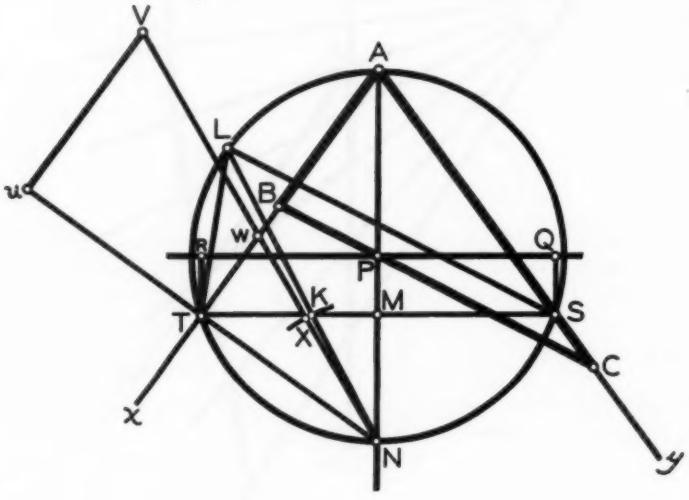

FIG. 9

Hence, to find the exact position of NKL, extend NT to U, making TU = NT; and at U erect a perpendicular UV to NU, of length UV = AP = t_a. Let NV cut AT at W; and lay off from W toward N,

$$WX = \frac{AP}{2} = \frac{t_a}{2}$$

With N as center and NX as radius describe arc cutting TS at K. Let NK meet circle ATNS in L, and join L to T and S. The ΔTLS is a triangle having the required parts, TS = a = l, $\angle$ TLS = $\angle$ A, and LK = AP = t_a. However ΔTLS is not in the required position, with

$\angle$ TLS coinciding with $\angle$ xAy. Accordingly we lay off on Ax, Ay the segments AB, AC equal to LT, LS respectively. Then BC passes through P, giving the required triangle ABC in position.

Since, on account of Ax, Ay being symmetrical about Az, AB′, AC′ may be laid off on Ay, Ax equal to LT, LS respectively, with B′C′ passing through P (B′, C′ and B′PC′ not shown in Fig. 9), we may readily prove, from the equality of ΔAPB and ΔA′PB′ that $\angle$ CPz = $\angle$ C′Pz, when z is at extremity of line AN. Since PB = PB′, then CP = C′P; and consequently Az is perpendicular to BB′ and CC′. Hence we are led to the formulation of the following theorem, just proved:

GENERALIZED THEOREM (7). *If the segments of two lines, drawn through any point in the bisector of an angle and intercepted by its sides,*

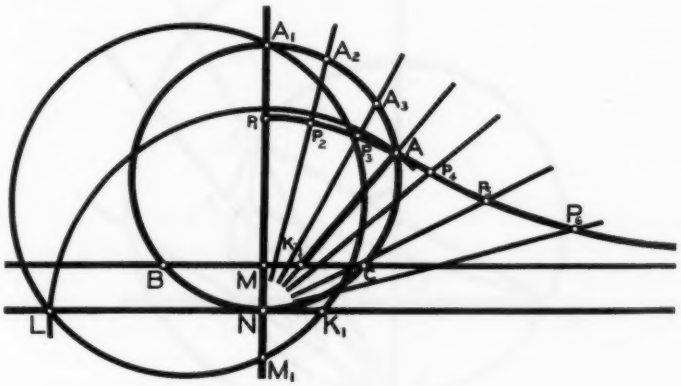

FIG. 10

are equal, the bisector is perpendicular to the cross-joins of corresponding ends of the line-segments.[11]

This same problem in construction may also be solved by the use of the conchoid, thereby manifesting the relation of the conchoid to the configuration of the internal-bisector problem.

(C) CONSTRUCTION 5. *To construct a triangle ABC, given a, A, t_a.*

Lay off BC = *a* on a horizontal line and erect perpendicular bisector at M (Fig. 10). Lay off at C below MC angle equal to $\frac{1}{2}$ $\angle$ A, the other leg cutting perpendicular bisector of BC at M, produced, at N. Draw

[11] The significance of this generalized theorem will be considered later on in this monograph.

circle through B, N, C meeting perpendicular bisector of BC at M in A_1. The problem now is to draw through N a straight line making the intercept on this, between the base BC and the circle $BNCA_1$, equal to t_a. Hence we draw the conchoid as shown in the figure, in which $MP_1 = KA = t_a$. Hence ΔABC is the required triangle. Since

$$NM \cdot NA_1 = NK \cdot NA = NK \cdot (NK + t_a) = \overline{NC^2},$$
$$NK = \tfrac{1}{2}(-t_a + \sqrt{(t_a) + 4\overline{NC^2}})$$

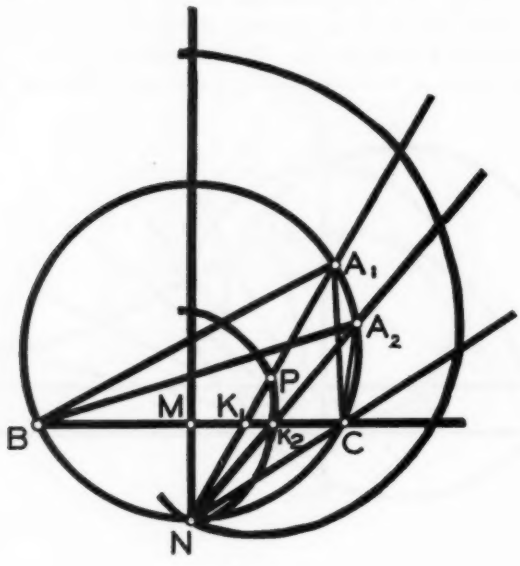

FIG. 11

Then lay off below N on MN produced, $NM_1 = NM$; and $NK_1 = NK$ to the right of NM on a perpendicular to it at N. The circle through A_1, K_1, M_1 will then cut K_1N produced in L, giving $NL = NA$ and the required triangle ABC.

(c) THE CARDIOID

The relation of the cardioid to the internal-bisector configuration is readily seen (Fig. 2) on laying off the triangles ABE, ACF on a common base BE (= CF). These triangles appear (Fig. 11) as A_1BC, A_2BC,

with BC as their common base. From the definition of the cardioid, the same length must be laid off from the circumference on lines drawn through a point in the circumference. Here the circle through A_1, A_2, C, B and cutting perpendicular bisector of BC at M, in N, supplies the circumference with N as the point on it from which the lines for the construction radiate. Let A_1N, A_2N cut BC in K_1, K_2 respectively. Choosing K_2A_2, the length of the bisector t_a (= AO, Fig. 2), as the given length to be laid off in both directions from the circumference on the rays through N, we construct the cardioid, cutting NK_1A_1 at P. Thus while one extremity of the given length t_a lies on the circle, the other extremity lies on the inner loop of the cardioid, since the bisector of the vertical angle is drawn from the vertex to the base of the triangle. But P, the extremity of $A_1P = t_a = A_2K_2$, must fall on the given base BC (O, extremity of AO, lies on BE and CF, Fig. 2). Since P on the cardioid and K_1 on the line BC must coincide, they both must fall at K_2. Hence A_1 must fall at A_2, making ΔA_1BC congruent to ΔA_2BC. Since this proves that $A_1B = A_2B$, or AB = AC (Fig. 2), the bisector problem is proved.

VII

In this section are submitted three new proofs of the internal-bisector problem, by the indirect method, which are interesting and elegant.

PROOF IX. Given ΔABC, with AD, BE the equal internal bisectors of the base angles BAC, CBA respectively (Fig. 12). Then we have three cases to consider, depending upon the relative size of the base angles. Suppose, first, $\angle BAC > \angle ABC$. Draw the circumcircle of the triangle AEB, cutting AD produced in Q. Draw a triangle congruent to ΔADB, with B now at A, A at B, and AD in the new position BD_1, where D_1 falls on circle with center B and radius BE. Since $\angle BAC > \angle ABC$, AD_1 falls above BE, meeting circumcircle of ΔAEB in P. Now since arc $\overset{\frown}{PB}$ < arc EPB, chord PB < chord EB. Therefore $BD_1 (= BE) > BP$; and consequently D is outside circumcircle of ΔAEB. Therefore $\angle AD_1B < \angle AEB (= \angle BQA)$. But $\angle AD_1B = \angle BDA$, by construction. Therefore $\angle BDA < \angle BQA$, which is impossible. Hence $\angle BAC \not> \angle ABC$. Second, by similar reasoning, it may be shown that $\angle BAC \not< \angle ABC$. Hence we conclude that $\angle BAC = \angle ABC$, giving AC = BC.

PROOF X. Given ΔABC, with AD, BE the equal internal-bisectors of the base angles BAC, ABC respectively (Fig. 13). Now we have three cases to consider, depending upon the relative size of the base

angles. First, let us suppose $\angle BAC > \angle ABC$. Through D draw line cutting BE at G, AC produced at C_2, and $\angle DGE = \angle EAD$, G falling between B and E since $\angle DGE > \angle DBG$. Now through B

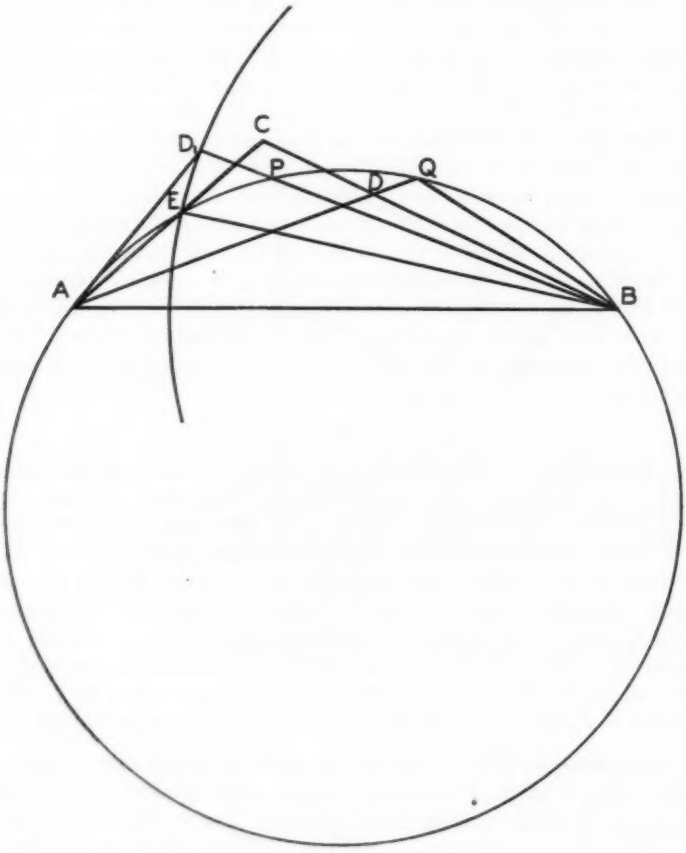

FIG. 12

draw line making with BE angle equal to $\angle DAC$, the other side of the angle meeting AC produced in C_1. Now $\Delta ADC_2 = \Delta EBC_1$, since

$$AD = BE,\ \angle EBC_1 = \angle DAC_2,\ \angle EC_1B = \angle AC_2D$$

since C_1B, C_2G are parallel. Hence

$$AC_2 = BC_1 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$\text{and } \angle C_2AD = \angle C_1BE \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

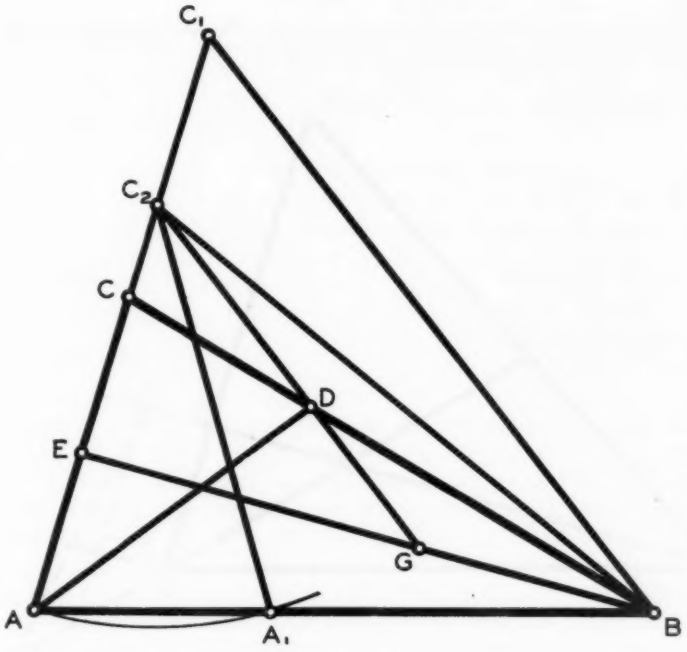

FIG. 13

Now describe arc with center C_2 and radius C_2A cutting AB at A_1. Since $\angle BAD > \angle ABE$ and $\angle DAC = \angle EBC_1$, we have

$$\angle AA_1C_2 (= \angle BAC) > \angle ABE + \angle EBC_1 (= \angle ABC_1)$$

and *à fortiori*, $> \angle ABC_2$, with A_1 falling between A and B.

Now

$$A_1C_2 = AC_2 = BC_1 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

by (1) above. But this is impossible; for by joining B to C_2 we have $A_1C_2 < BC_2$ since A_1 falls to the right of the foot of the perpendicular

from C_2 to AB, and $BC_2 < B_1C_1$ since C_1 falls beyond C_2 from the foot of the perpendicular from B to AC_1, giving $A_1C_2 < BC_1$, which is contradicted by (3). Hence $\angle BAC \not> \angle ABC$. Similarly, it may be shown that $\angle BAC \not< \angle ABC$. Hence $\angle BAC = \angle ABC$, giving AC = BC.

The third new indirect proof, which follows, like the second, has the merit of employing only theorems of Book I.

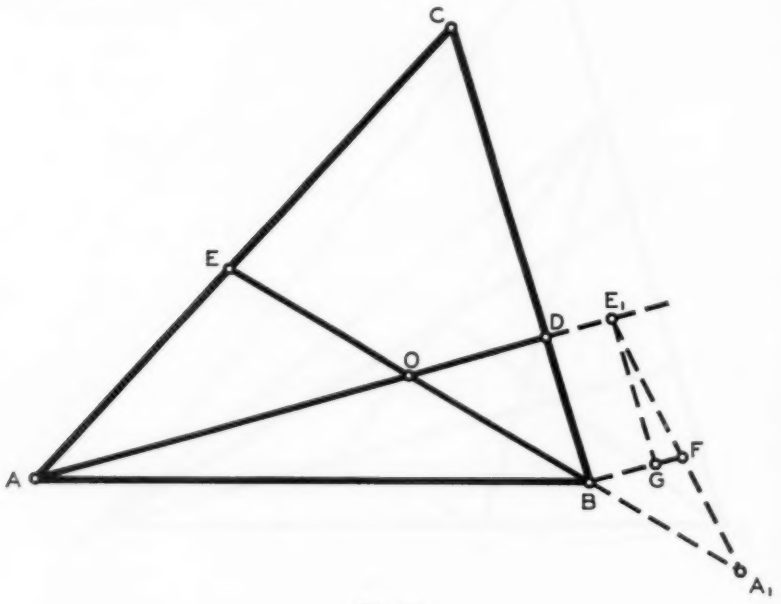

FIG. 14

PROOF XI. Given ΔABC, with AD, BE, the equal internal-bisectors of the base angles BAC, ABC respectively, intersecting in O (Fig. 14). First let us suppose that $\angle BAC < \angle ABC$. Then $OA > OB$. Since AD = BE, therefore $OD < OE$. Extend AD to E_1, making $OE_1 = OE$, and extend EB to A_1 making $OA_1 = OA$, E_1 lying beyond D from O and A_1 beyond B from O. Join A_1 to E_1 by a straight line.

Now $\Delta OA_1E_1 = \Delta OAE$, giving $\angle OA_1E_1 = \angle OAE$ and $\angle OE_1A_1 = \angle OEA$. Since

$$\angle AOE + \angle OEA + \angle EAO = \angle BOD + \angle ODB + \angle DBO$$

therefore

$$\angle DBO - \angle EAO = \angle OEA - \angle ODB$$

But $\angle OAE < \angle DBO$, by hypothesis, and consequently

$$\angle ODB < \angle OEA \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Through B draw line parallel to AE_1, through E_1 a line parallel to DB, these lines meeting at G with G between B and F, since $\angle DE_1G (= \angle ODB) < \angle OE_1A_1 (= \angle OEA)$, from (1). Let BG prolonged meet A_1E_1 at F. Hence

$$DE_1 (= BG) < BF \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

But

$$\angle OEA (= \angle OE_1A_1 = \angle BFA_1) = \angle ACB + \angle EBC$$

Therefore

$$\angle BFA_1 > \angle EBC (= \angle OBD) > \angle BA_1F (= \angle OAE)$$

by hypothesis, giving

$$BA_1 > BF \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Therefore $BA_1 > DE$, from (2) and (3), or $OA_1 - OB > OE_1 - OD$, giving $OA_1 + OD > OE_1 + OB$ or $AO + OD > OE + OB$ or $AD > BE$, which is contrary to the hypothesis. Hence $\angle BAC \not< \angle ABC$.

Similarly, with subsidiary figure drawn to left of AC, it may be shown that $\angle BAC \not> \angle ABC$. Hence $\angle BAC = \angle ABC$, giving $AC = BC$.

VIII

The above investigations, in particular Generalized Theorem 7, Section VI, suffice to disclose the real crux of the problem under discussion. As customarily stated, the internal-bisector problem is misleading, in that it throws the stress upon the wrong features, and veils the essential elements, of the geometrical configuration. The condition that the two equal lines drawn from *the extremities of the base of a triangle* shall be *internal bisectors* of the base angles is really incidental so far as the real problem is concerned. Stress upon the word "triangle" diverts us from the correct mode of approach. The fundamental problem, as we shall see, is that of antiparallels[12] and their relations to the sides of an angle

[12] Definition: If two line-segments B_1C_1, B_2C_2, joining points B_1 and C_1, B_2 and C_2, of the sides AB, AC respectively of an angle BAC, are such that $\angle AB_1C = \angle AC_2B_2$, the lines B_1C_1, B_2C_2 are said to be antiparallels with respect to $\angle BAC$.

and its bisector. The essential and indispensable conditions for the generalized theorem are: (1) the lines through a point in the bisector of an angle must meet the sides of the angle; and (2) the segments of the lines, included between the sides of the angle, shall be equal. No triangle is mentioned in the generalized theorem, already proved above, which for convenience will be repeated here:

GENERALIZED THEOREM (7). *If the segments of two lines, drawn through any point in the bisector of an angle and intercepted by its sides, are equal, the bisector is perpendicular to the cross-joins of the corresponding ends of the line segments.*

Immediate and inevitable consequences are that both triangles having the angle-vertex as triangle-vertex and the cross-joins of corresponding ends of the line-segments as bases, are isosceles.

Another theorem intimately connected with this theorem is:

GENERALIZED THEOREM (7a). *Two equal line-segments, included between the sides of an angle and passing through a point in its bisector, are antiparallels.*

Still another theorem of like character is:

GENERALIZED THEOREM (7b). *Two equal line-segments, passing through a point in the bisector of an angle and included between its sides, make equal angles with the bisector.*

This generalized theorem is of fundamental importance, lying as it does on the frontier line between Euclidean and the non-Euclidean geometries. Indeed, it may be said to play a criterial rôle in the theory of parallels. As a substitute for Euclid's Fifth Postulate, upon which Euclidean geometry depends, we may employ LEGENDRE'S POSTULATE. *From any point whatever taken within an angle we can always draw a straight line which will cut the two arms of the angle.*[13]

By means of this postulate as a substitute for Euclid's Fifth Postulate, employing the identical figure of the crucial generalized theorem, stated above in three alternative forms, we are enabled to prove Euclid's Fifth Postulate as a theorem, together with the ordinary theory of parallels resulting in the demonstration that the sum of the angles of a triangle make up two right angles.[14] The argument follows.

[13] Legendre was anticipated in the formulation and use of this hypothesis by J. F. Lorenz: *Grundriss der reinen und angewandten Mathematik* (Helmstedt, 1791).

[14] Adrien Marie Legendre: "Réflexions sur différentes manières de démonstrer la théorie des parallèles ou le théorème sur la somme des trois angles du triangle," *Mem. Ac. Sci.* **13**: (Paris, 1833). Compare Roberto Bonola: *Non-Euclidean Geometry*, English translation by H. S. Carslaw, pp. 55–60 (Chicago, 1912).

Let Oy and Mu be two straight lines making an acute and a right angle, respectively, with a given line OMz; and lay off $\angle$ MOx = $\angle$ MOy (Fig. 15). By Legendre's Postulate there passes through M a line meeting the sides of $\angle$ xOy (in A and B). If this line is Mu, the theorem is fulfilled. If this line (AB) is different from Mu, then also a line symmetrical to AB with respect to OMz meets the sides of the $\angle$ yOx (in A′ and B′). Then Mu, drawn within the $\angle$ OMB, meets Oy (in S), proving for Case I, when one angle is right and the other acute, Euclid's Fifth Postulate for a special case: "Two lines making angles of

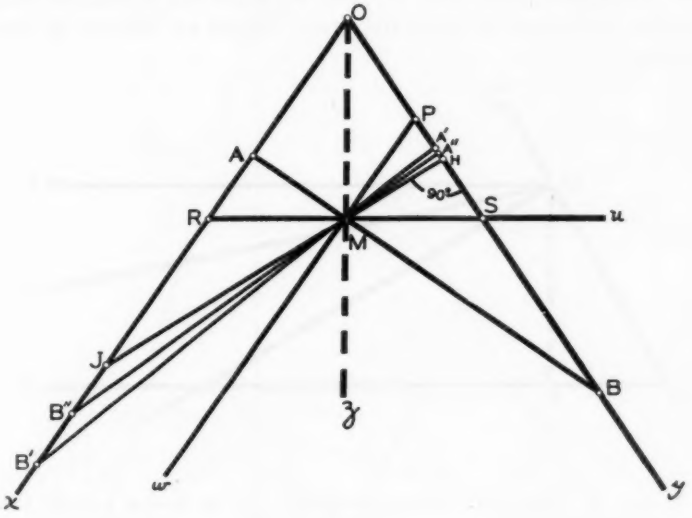

FIG. 15

90° and less than 90° respectively with a given line intersect each other." For Case II, when each of the angles is acute, the theorem is also proved, since any line through M lying within $\angle$ OMu obviously meets Oy.

Let us now consider Case III (Fig. 16). Through M draw a line Mv making with MO an obtuse angle OMv such that $\angle$ MOy + $\angle$ OMv < 180°. Lay off $\angle$ zMt = $\angle$ MOy, which is acute. Now let fall from M the line MH perpendicular to Oy. If $\angle$ HMv < 90°, Mv and Oy meet (Case I). If $\angle$ HMv = 90°, vM produced will meet yO produced (Case I). If $\angle$ HMv = 90°, we have, since by hypothesis $\angle$ MOy + $\angle$ Omv < 180° and $\angle$ zMt = $\angle$ MOy by construction, Mv

falls within the ∠ OMt, giving ∠ HMv < 90°, since Mt is parallel to Oy. Hence Oy and Mv intersect, by Case I, thus proving Euclid's Fifth Postulate for all cases.

We shall next proceed to give two direct demonstrations of the Generalized Theorem (7). It is necessary, in these proofs, to assume the constructions: to draw a parallel, and to draw a perpendicular, to a given line. These constructions, as ordinarily given in the test-books, make use of the circle. If we are to establish our proof by means of the theorems of Book I only, we shall have to show that the two constructions mentioned above may be made by ruler and sect-carrier only, without employing the aid of the circle. Hence we shall set up three lemmas.

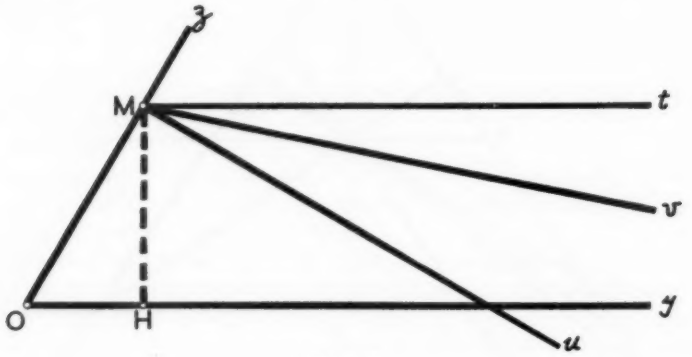

FIG. 16

LEMMA I. *Through a point outside of a line to draw a parallel to the line.* Given line l and point P outside this line. Through P draw a random line to meet line l in Q. Lay off, beyond Q from P, QR = PQ. Through R draw another random line to meet l in S, extending RS to T, making ST = RS. Then the straight line joining P and T will be parallel to QS.

LEMMA II. *To construct a right angle at a given point.* Through the given point P draw a line at random on which is laid off any convenient length PQ. Through Q draw another line at random, distinct from QP, on which we lay off QR = QS = QP. Join R to S and P. Then from the two isosceles triangles PQS, PQR, and the triangle PQS we readily find that the ∠ RPS is a right angle.

LEMMA III. *To erect a perpendicular to a given line.* Through P, a

point on the given line l, draw two random lines, distinct from l; lay off on each any chosen length PQ = PR, and from P lay off on l, PA = PB = PQ (Fig. 17). Join A, B to R, Q and let AR meet BQ in S, AQ meet BR in T. Then TS is perpendicular to line l. This follows from Lemma II, giving $\angle$ AQB = $\angle$ ARB = 90°, and the theorem in Book I on the concurrence of the three perpendiculars from the vertices of a triangle (ABT) to the opposite sides.

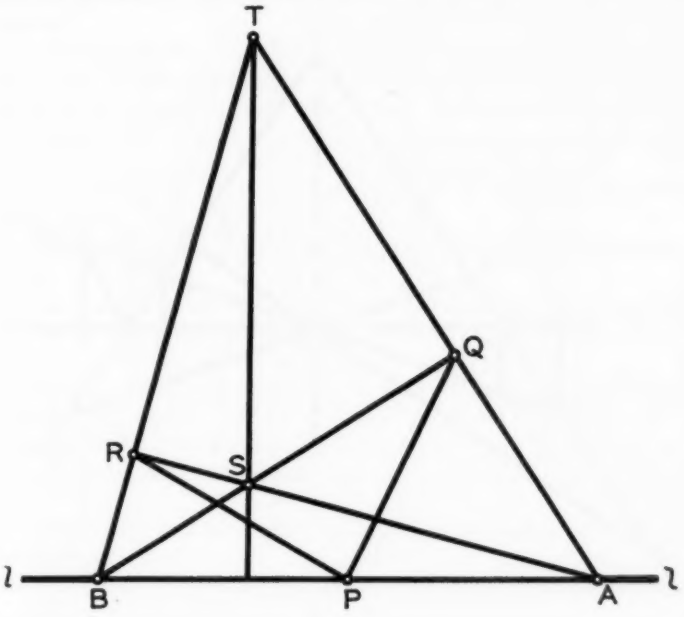

FIG. 17

GENERALIZED THEOREM (7). SECOND PROOF.

Given $\angle$ xOy with bisector Oz, and two equal line segments AB, A′B′ drawn through a point M on the bisector Oz (Fig. 15). Through M draw line Pw parallel to Ox (Lemma I), Mu perpendicular to Oz (Lemma III), meeting Oy in S, and the perpendicular to Oy, meeting it in H and Ox in J (Lemmas I and III). Because of symmetry and the nature of parallelism, we need to confine our attention only to lines A″B″ drawn within $\angle$ PMu. Obviously there are two cases. *Case I.*

Suppose A″B″ falls within ∠ HMP. Then MH < MA″ < MP, and MJ < MB″ < Mw (infinite in length). Hence A″B″ ranges continuously in value from HJ to Pw (infinite in length). *Case II.* Suppose A″B″ falls within ∠ HMS (Fig. 18). Through A″, B″, R, S draw perpendiculars to RS, namely A″ Q, B″ N, RL, and SV. Lay off MT = MB″ and on MS drop from T a perpendicular Tu. Now MA″ > MQ, LM > RM, and B ″ L > NR (= Su) > QS, since ∠ VSA″ > ∠ VST. Adding together these inequalities we have A″B″ > RS. Similarly we may

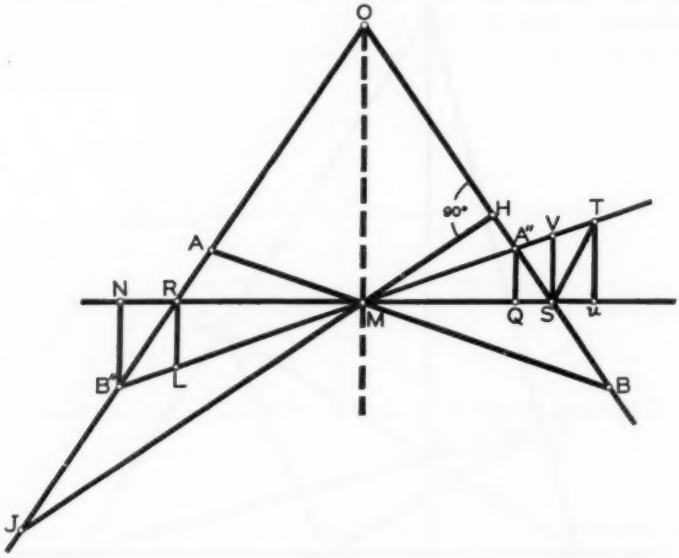

FIG. 18

prove that A″B″ < HJ; and that any additional line A‴B‴ (not drawn) falling within ∠ A″ MS satisfies the inequalities RS < A‴B‴ < A″B″. Hence A″B″ ranges continuously in value from RS to HJ.

From Cases I and II it follows that every such line A″B″ passes continuously through all values between RS and Pw (infinite in length), and consequently for that range is in one-to-one correspondence with the real number system. Hence there is but *one* such position corresponding to AB, viz. A″B″ = AB. Hence A″B″ coincides with A′B′, which is determined in position by the construction given above.

We conclude that Oz is perpendicular to AA′ and BB′, and hence that the triangles AOA′ and BOB′ are isosceles. We should note, furthermore, that

$$MA = MA',\ MB = MB',\ \angle OMA = \angle OMA',\ \angle OMB = \angle OMB'$$

Since $\Delta AOB = \Delta A'OB'$, we have also proved Theorem 6, Section IV.

It may be observed that, since $\angle OBM = \angle OB'M$, we may state a theorem intimately corrected with Generalized Theorem (7) as follows:

GENERALIZED THEOREM (7c). *If two line-segments, drawn through a point in the bisector of an angle and intercepted by its sides, are equal, they divide proportionally the base angles (both internal and external) of the two triangles, both of them isosceles, formed by the sides of the angle and the cross-joins of the corresponding ends of the two line-segments.*

The following theorems are consequences of the Generalized Theorems (7), (7a), (7b), (7c):

THEOREM 8. *Equal antiparallels to the sides of an angle meet on the bisector of the angle.*

THEOREM 9. *Of two line-segments passing through a point in the bisector of an angle and intercepted by its sides, that one which makes the greater angle with the bisector is the shorter.*[15]

As special cases of the generalized theorem we may note the following positions of AB, A′B′, in addition to that of internal bisectors of the base angles of $\Delta OBB'$: the medians of the triangle drawn from B, B′ to the opposite sides, the symmedians, the perpendiculars to the opposite sides, etc.[16]

A straightforward generalization of the internal-bisector problem is the following:

GENERALIZED THEOREM (8). *If two lines, dividing proportionally the*

[15] Theorems (7c), 8 and 9 are variously interconnected.

[16] Concerning the symmedians, consult *L'Intermédiaire des Mathématiciens* **2** (1874), contributions by Alauda, Dellac, Sollertinsky, Lemoine and Tarry. The most elegant indirect proof known, applicable alike to internal bisectors and symmedians, is that of Tarry, *l.c.* Much more elaborate indirect proofs for the internal bisectors are those of Sylvester and B. L. Smith in the former's article, *l.c.* The briefest proof, which is *indirect*, is that referred to in footnote 10. An extended direct proof of the internal bisector problem, by the use of Book I, is that of G. I. Hopkins in E. S. Loomis, Original Investigation on How to Attack an Exercise in Geometry (Boston, 1901). Cf. Archibald Henderson, chapter "Mathematics" in Roads to Knowledge (New York, 1932). Except for the proof of Hopkins, I know of no direct proofs, by the use of Book I only, except those of the present monograph.

base angles of a triangle internally, are cut by the opposite sides in two equal line-segments, the triangle is isosceles.

A proof, by the indirect method, follows. Given ΔABC, with Ax, By dividing the base angles BAC ($= \alpha$), ABC ($= \beta$) proportionately and meeting the sides AC, BC in D, E respectively, so that $\angle BAD = n\alpha$, $\angle ABE = n\beta$, $(o < n < 1)$, and AD = BE (Fig. 19). Now three

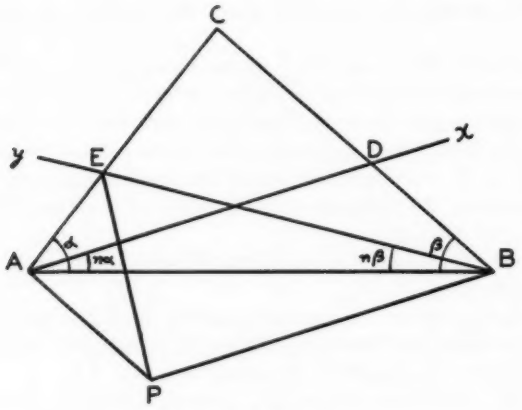

FIG. 19

cases arise, depending upon the relative size of α and β. *Case I.* Suppose $\angle \alpha > \angle \beta$. Then $\angle BAD > \angle ABE$, giving

$$BD > AE \quad \ldots\ldots (1)$$

Through A, B draw lines parallel to CB, DA respectively, meeting in P, and join P to E. Then BP = AD = BE, making

$$\angle BEP = \angle BPE \quad \ldots\ldots (2)$$

But since PA (= BD) > AE, from (1),

$$\angle AEP > \angle APE \quad \ldots\ldots (3)$$

Adding (2) and (3) we have

$$\angle BEA > \angle BPA \quad \ldots\ldots (4)$$

Now

$$\angle BAE + \angle ABE + \angle BEA = \angle ABP + \angle BAP + \angle BPA \equiv 180°$$

or

$$\angle\alpha + \angle n\beta + \angle BAE = \angle n\alpha + \angle\beta + \angle BPA$$

Hence

$$\angle BAE - \angle BPA = (n-1) \angle (\alpha - \beta)$$

which is impossible, since the left side of the equation and $\alpha - \beta$ are positive, but $n - 1$ is negative. *Case II.* If we assume $\angle \alpha < \angle\beta$, a similar contradiction may be shown, by drawing through A, B lines parallel to EB, CA respectively. Hence $\angle\alpha = \angle\beta$, and therefore $AC = BC$.[17]

By the use of the formula for the length of the internal bisector, we find by setting $\overline{AD}^2 = \overline{BE}^2$,

$$c(a-b)(a+b+c)(c^3 + 3abc + bc^2 + ab^2 + ac^2 + a^2b) = 0$$

giving the unique solution $a = b$. If however we adopt the same method for the external bisectors of the same base angles, a different situation develops, since we find

$$c(a-b)(a+b+c)(c^3 + 3abc - bc^2 - ab^2 - ac^2 - a^2b) = 0$$

giving two possible solutions: $a = b$ (1) and $c^3 + 3abc - bc^2 - ab^2 - ac^2 - a^2b) = 0$ (2). Equation (1) gives the isosceles triangle case; equation (2) may be put in the form $4Rr_e = ab + c^2$, where R is the radius of the circumcircle of the triangle and r_e is the radius of the circle externally tangent to the side AB.[18]

GENERALIZED THEOREM (7). THIRD PROOF. Given $\angle A$ with bisector AO, and equal line segments BOE, COF intercepted between sides of $\angle A$ (Fig. 20). Drop a perpendicular on AO produced, meeting it at N and EB at L (Lemmas II and III). Extend LN to L_1, making $NL_1 = LN$. Draw line through O and L_1, meeting the sides AB,

[17] Of this theorem I have seen no direct proof.

[18] *Mathesis* **15**: 261–2 (1895). Compare also Sylvester, *l.c.* for a trigonometric analysis which merely skirts the edges of the problem of the external bisectors. Apparently no solution, solely by geometrical methods as expressed by the condition $4Rr_e = ab + c^2$, is available. Consult, however, W. E. Heal: Paper II. Relating to the Demonstration of a Geometrical Theorem, *American Mathematical Monthly* **25**: 182–3 (1918).

AC of the given angle BAC at E_1, B_1 respectively. Since $\angle NOL_1 = \angle NOL$, and $\angle EOB_1 = \angle EOB$, therefore $\angle NOE_1 = \angle NOE$ and

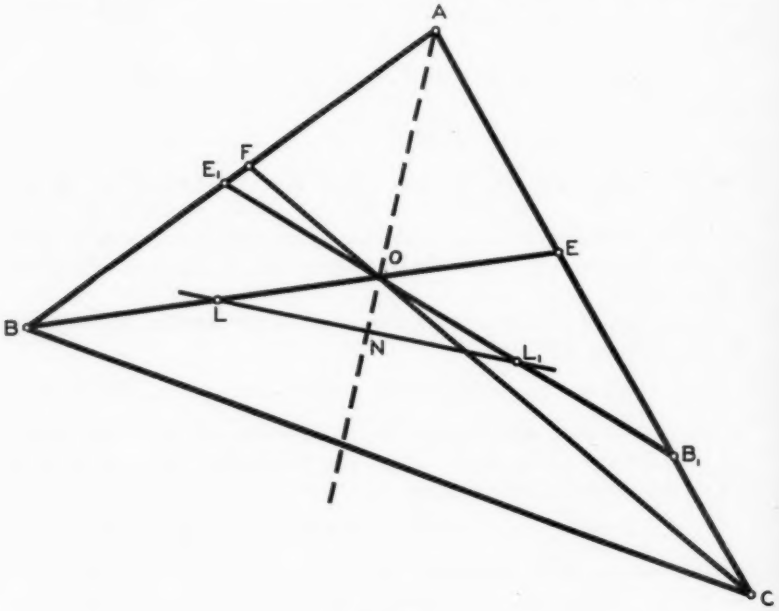

FIG. 20

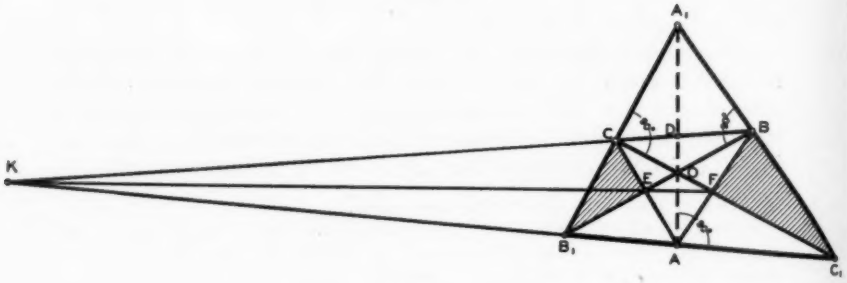

FIG. 21

$\angle AOE_1 = \angle AOE$. Hence $\Delta AOE_1 = \Delta AOE$, giving $AE_1 = AE$ and $\angle AE_1O = \angle AEO$. There $\Delta A_1E_1B_1 = \Delta AEB$. Therefore $AB_1 = AB$

and $E_1B_1 = EB$. From the symmetry of the figure about AO, the continuous increase of length of intercepted segment from RS to Pw (Fig. 15) and the uniqueness of the construction of E_1B_1, it follows that FC must coincide with E_1B_1. Hence $EB = E_1B_1 = FC$; and therefore $AB = AC$, and AO is perpendicular to EF and BC at their respective mid-points.

IX

Since the lines AB, AC, BE, CF constitute the nucleus of a complete quadrilateral, the generalized theorem falls in the domain of projective geometry. It nevertheless has a semi-metrical character, because of the condition that the segments of the lines through a point on the bisector of the given angle and intercepted between its sides, are equal. The following proof of the internal-bisector problem brings into clear relationship the projective, harmonic, and metric features of the theorem,

Given ΔABC, with internal bisectors AD, BE, CF of the angles A, B, C, meeting at O (Fig. 21). Prolong BE and CF to meet the perpendicular to AO at A, in the points B_1, C_1 respectively. Join B_1 to C and C_1 to B. Since AO and AB_1 are the internal and external bisectors of $\angle$ BAC, therefore $BOEB_1$ and $COFC_1$ are harmonic ranges with O as self-corresponding point. Therefore BC, FE, C_1B_1 are concurrent in the point K; and since the triangles BFC_1, CEB_1 are in perspective, then by Desargues's Theorem, B_1C, C_1B; B_1E, C_1F; CE, BF meet in the collinear points A_1, O, A respectively. Now BC and FE are perpendicular to AOA_1 [Generalized Theorem (7) Section VIII], and hence parallel to C_1B_1. Hence K goes to infinity; and D, paired with K in the harmonic range BDCK, bisects BC. Accordingly $AB = AC$.

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NOTES ON THE GENUS FLINDERSIA R. Br. AND THE SYSTEMATIC ANATOMY OF THE IMPORTANT FLINDERSIAN TIMBERS INDIGENEOUS TO QUEENSLAND

By Ellwood S. Harrar

Plates 24–26

INTRODUCTION

The genus *Flindersia* R. Br., since it was first recognized as distinct from other related groups, has been subject to considerable taxonomic disagreement among systematists. Bentham and Hooker (1862–1867) originally placed *Flindersia* in the Meliaceae. Bailey (1899–1902) likewise classified it with this family when he compiled "The Queensland Flora." Engler and Gilg (1924) noted the occurrence of secretory tissue in the leaves and cortex of several species and promptly transferred the genus to the Rutaceae, although Hutchinson (1926) still holds to the concepts of Bentham and Hooker. Welch (1931) suggests that the group might occupy a position midway between the Rutaceae and the Meliaceae, and White (1931), after carefully examining floral characters, states that *Flindersia* appears to be more closely related to the Rutaceae than to the Meliaceae but favors the formation of a new family, Flindersiaceae.

The present study has a two-fold purpose: (1) to present information of diagnostic value concerning the important commercial timbers of this genus which are indigenous to Queensland, and (2), to ascertain if there is sufficient evidence, based upon wood anatomy, to determine accurately the correct taxonomic position of *Flindersia*.

SIZE AND DISTRIBUTION

According to White (1921) *Flindersia* comprises 18 species of trees only 3 of which occur naturally beyond Australian shores. The Queensland flora includes 14 or 15 species; these are widely scattered throughout the state, some occurring in the rain-forests and others in much less humid regions. Economically the group is rather important and is

especially noted for the very fine cabinet woods and structural timbers which it produces.

MATERIALS

The materials which served as a basis for this study were obtained from the Queensland Service through the coöperation of the Provisional Forestry Board, Brisbane, Queensland. Herbarium sheets from the identical tree accompanied each specimen of wood and all were checked for accuracy of identification by government botanists before shipment to the United States. The wood samples now reside in the collections of the Department of Wood Technology, The New York State College of Forestry at Syracuse, New York, and the herbarium material is on file at the New York Botanical Garden, Bronx Park, New York City. Additional wood samples, many of them trade samples from the collections of the New York State College of Forestry, and from those of the College of Forestry, University of Washington, Seattle, Washington, were used for purposes of comparison and for the collection of additional anatomical data. The species examined are indicated below:

1. *F. acuminata* C. T. W.
2. *F. australis* R. Br.
3. *F. bennettiana* F. v. M.
4. *F. bourjotiana* F. v. M.
5. *F. brayleyana* F. v. M.
6. *F. collina* Bail.
7. *F. ifflaiana* F. v. M.
8. *F. oxleyana* F. v. M.
9. *F. pubescens* Bail.
10. *F. schottiana* F. v. M.

CHARACTERISTICS OF FLINDERSIAN WOOD

Physical properties. Sapwood creamy white to silvery white or yellowish white, gradually merging into somewhat darker heartwood, except in those woods where these two zones cannot be differentiated; heartwood creamy white, silvery white, pale yellow, light brownish yellow, light golden brown or rarely mahogany-red or coppery red; dull or with a pronounced pearly lustre or silky sheen; occasionally oily to the touch; with an aromatic odor, rancid, or odorless; in weight ranging from approximately 35 to 60 lbs. per cubic foot air-dry; usually even-

textured; straight, undulate, or firmly interlock-grained; plainly or handsomely figured.

Anatomical features

Growth rings occasionally evident at high magnifications but not sharply defined, usually delineated by narrow to relatively wide lines or bands of dense fibrous tissue where growth increments adjoin.

Vessels variable in size but of nearly uniform diameter within a species, oval, orbicular, and polygonal (x),[1] solitary, in 2–8 (mostly 2–4) radial rows, and occasionally in small clusters not exceeding 6, usually surrounded by a narrow sheath of parenchyma which is often interrupted by fibers and wood rays flanking the vessels; vessel members variable in length, truncate or with short tails at one or both ends, commonly plugged at the junctures or wholly occluded with yellow to reddish brown gummy infiltration or white granular deposits; perforation plates simple, nearly horizontal; inter-vessel pits irregularly polygonal, crowded, 4–8 microns in width; pits leading from vessels to ray and longitudinal parenchyma similar to but smaller than those of the inter-vessel type; tyloses wanting.

Fibers usually less than 30 microns in diameter, thin- to extremely thick-walled, non-septate, aligned in radial rows which are further aggregated into extensive tracts; inter-fiber pits minute, orbicular to slit-like, bordered.[2]

Longitudinal parenchyma metatracheal, paratracheal, and diffuse, in cambiform rows of 2–8 units along the grain, occasionally further divided into crystal loculi: (a) *metatracheal* paranchyma abundant (in certain woods this is the most conspicuous feature on the transverse section), the cells forming 2–40 plus (mostly 2–12) seriate bands (x) which occur with considerable regularity in some woods and very irregularly in others; (b) *paratracheal* parenchyma usually forming a 1–3 seriate sheath, often dissected by fibrous tissue and rays; (c) *diffuse* parenchyma seldom conspicuous, the cells occurring as isolated individuals scattered through the tracts of fibrous tissue; cells of all types occasionally crystalliferous, (except in *F. bourjotiana*) those of the "a" and "b" types occasionally thick-walled; inter-parenchymatous pits minute.

Wood rays plainly visible or indistinct without a lens, unstoried,

[1] x. r. t. = transverse, radial, and tangential surfaces respectively.

[2] Pit borders in the very thick-walled fibers are usually poorly developed and in some instances appear to be wholly lacking.

homogeneous, or rarely bordering on the heterogeneous type, heterogeneous in *F. collina*, 1–7 seriate, of nearly uniform width within a species, but quite variable in height; inter-ray cell pits minute; gummy infiltration sparse; crystals wanting (except in the marginal upright ray cells in *F. collina*).

Gum canals present at wide intervals, restricted to the broader bands of metatracheal parenchyma, solitary or in tangential rows of 2-many.

Pertinent features of the species

This study has revealed that flindersian timbers possess numerous physical and anatomical departures of sufficient magnitude to permit of their specific identification. To facilitate comparisons, the significant properties of each have been noted and recorded in Table I. A key for these woods, based on both their microscopic and macroscopic characteristics, also has been compiled.

KEY TO THE WOODS

1. Heartwood reddish brown, mahogany-red, or copper-colored, aromatic ..... *F. brayleyana*
1. Heartwood ranging through shades of creamy white, silvery white and grayish white to yellow-brown, golden brown or brownish white, never tinged with red, odorless or occasionally rancid, but never aromatic 2
2. Heartwood with a rancid odor, oily to the touch 3
2. Heartwood odorless or if scented not rancid, not oily to the touch 4
3. Wood rays plainly visible without a lens, 1–6 seriate; ray cells 40–50 microns in diameter (t); metatracheal parenchyma cells thin-walled ..... *F. australis*
3. Wood rays not discernible without a lens, 1–3 seriate; ray cells 30–35 microns in diameter (t); metatracheal parenchyma cells thick-walled ..... *F. ifflaiana*
4. Vessel orifices plainly visible without a lens 5
4. Vessel orifices indistinct without a lens 7
5. Fiber walls uniformly thin; metatracheal parenchyma very sparse ..... *F. acuminata*
5. Fiber walls variable in thickness, those in the outer limits of growth rings the thickest 6
6. Wood rays 1–5 seriate, 32–40 cells high; growth rings poorly defined; longitudinal parenchyma commonly crystalliferous ..... *F. pubescens*
6. Wood rays 1–3 seriate, 24–30 cells high; growth rings sharply defined; longitudinal parenchyma nearly or wholly devoid of crystals ..... *F. bourjotiana*
7. Wood rays 1–2 seriate, 12–18 cells high; growth rings sharply defined. ..... *F. schottiana*
7. Wood rays 1–7 seriate, 30–52 cells high; growth rings poorly defined 8
8. Vessels mostly in 2–4 radial rows (x), 14–28 per mm². metatracheal parenchyma sparse ..... *F. oxleyana*
8. Vessels mostly solitary and radially paired (x), 10–17 per mm²; metatracheal parenchyma abundant 9

TABLE I

Diagnostic features of the woods

SPECIES	HEARTWOOD				SEASONAL RINGS	VESSELS				
	Color	Odor	Feel	Average weight in pounds per cubic foot		Orifices visible without a lens	Arrangement	Minimum and maximum No. per mm².	Average and maximum diameter	Average length of vessel members
F. acuminata	Creamy white to light silvery brown, lustrous	None	Dry	35	Poorly defined	Yes	Mostly paired	5–15	200–250 microns	600 microns
F. australis	Yellowish brown to golden brown, dull	Rancid	Oily	50	Not evident	Yes	Mostly paired	12–20	Same	650 microns
F. bennettiana	Brownish white to pale straw-colored, lustrous	None	Dry	55	Poorly defined	No	Mostly paired	10–15	150–175 microns	450 microns
F. bourjotiana	Creamy white to brownish white, lustrous	None	Dry	45	Sharply defined	Yes	Mostly solitary and paired	7–15	175–210 microns	650 microns
F. brayleyana	Reddish brown to mahogany-red or copper-colored	Aromatic	Dry	40	Sharply defined	Yes	Same	5–15	175–225 microns	Same
F. collina	Creamy white, lustrous	None	Dry	60	Poorly defined	No	Same	10–17	130–175 microns	450 microns
F. iflaiana	Golden yellow to yellowish brown, somewhat lustrous	Rancid	Oily	60	Not evident	Yes	Mostly in 3–6 radial rows	8–20	200–260 microns	700 microns
F. oxleyana	Light golden brown to yellowish brown, lustrous	None	Dry	50	Poorly defined	No	Mostly in 2–4 radial rows	14–28	110–150 microns	525 microns
F. pubescens	Silvery white to light silvery brown, lustrous	None	Dry	40	Poorly defined	Yes	Mostly paired	6–9	200–240 microns	625 microns
F. schottiana	Silvery gray to brownish white, lustrous	None	Dry	45	Sharply defined	No	Same	12–20	125–175 microns	450 microns

SPECIES	FIBERS		LONGITUDINAL PARENCHYMA*		RAYS					
	Walls	Pits	Metatracheal	Paratracheal	Visible without a lens	Seriation	Ave. and max. height in cells	No. per mm. across the grain	Composition	Ave. dia. of ray cells
F. acuminata	Uniformly thin	Orbicular	Sparse, thin-walled, in 1–6 seriate bands	1–3 (mostly 1) seriate	Yes	1–5	32–41	4–6	Homogeneous	16–24 microns
F. australis	Uniformly very thick	Slit-like	Abundant, thin-walled, in 1–8 seriate bands	1–2 seriate	Yes	1–6	42–54	3–5	Homogeneous	40–50 microns
F. bennettiana	Variable, thickest in outer limits of ring	Lenticular to slit-like	Abundant, thin-walled, in 1–7 seriate bands	Uniseriate	Barely	1–6	40–52	3–6	Homogeneous	15–20 microns
F. bourjotiana	Same	Same	Abundant, thin-walled, in 1–7 seriate bands	1–2 seriate	Barely	1–3	18–33	4–7	Homogeneous	25–30 microns
F. brayleyana	Same	Lenticular	Abundant, thin-walled, in 1–40 (mostly 1–12) seriate bands	Sparse, occurring as an occasional cell or in 2's and 3's	Barely	1–4	24–30	3–5	Homogeneous	18–22 microns
F. collina	Same	Slit-like	Abundant, thin-walled, in 2–12 seriate bands	1–2 seriate	Yes	1–7	31–51	4–6	Heterogeneous	25–30 microns
F. ifflaiana	Uniformly thick	Same	Abundant, thick-walled, in 1–7 seriate bands	Uniseriate	No	1–3	25–36	6–9	Homogeneous	30–35 microns
F. oxleyana	Variable, thickest in outer limits of ring	Orbicular to lenticular	Sparse, thin-walled, in 2–10 seriate bands	1–4 seriate	Yes	1–6	34–48	4–6	Homogeneous	25–30 microns
F. pubescens	Same	Same	Abundant, thin-walled, in 2–10 seriate bands	1–3 seriate	Yes	1–5	32–40	4–7	Homogeneous	25–35 microns
F. schottiana	Same	Same	Abundant, thin-walled, in 2–7 seriate bands	1–2 seriate	No	1–2	12–18	3–6	Homogeneous	25–30 microns

* Crystalliferous cells abundant except in *F. bourjotiana.*

9. Wood rays heterogeneous, the cells 25–30 microns in diameter (t), occasionally crystalliferous; metatracheal parenchyma bands 2–12 seriate.... *F. collina*
9. Wood rays homogeneous, the cells 15–20 microns in diameter (t), non-crystalliferous; metatracheal bands 1–7 seriate..... *F. bennettiana*

DISCUSSION

Since the pertinent physical and anatomical properties which characterize flindersian wood have been already reviewed, it now becomes expedient to compare them with those which feature the Meliaceae and Rutaceae, respectively.

The timbers of the Meliaceae, as well as those of the Rutaceae, themselves exhibit a wide range of physical and anatomical properties. On the other hand, there are several species included in each of these two families which possess numerous features in common. Woods of this sort not infrequently suggest close botanical affinity, and in many instances it is only after they have been critically examined that their real taxonomic relationships become apparent. Included among woods of this type are those produced by members of the genus *Flindersia*. In this group of woods the arrangement of vessels and the distribution of longitudinal parenchyma closely resembles that of many rutaceous, as well as a large number of meliaceous woods. The perforation plates, inter-vessel pitting, pits between vessels and ray or longitudinal parenchyma are likewise all so similar that they are of practically no value diagnostically. It is, therefore, rather obvious that the true systematic position of *Flindersia* can be determined only after comparisons have been made with those physical and anatomical features which alone give real character respectively to the Meliaceae and to the Rutaceae.

Meliaceous woods are pink, red, or reddish brown for the most part, while those belonging to the Rutaceae usually vary through shades of lemon-yellow to light yellowish brown or brownish white. With respect to color the heartwood of *F. brayleyana* is typical of many woods belonging to the mahogany family,[3] but the colors of the nine other species examined are much more characteristic of woods included in the rue family. Scented woods are featured by several genera of both families. Those included in the Meliaceae are commonly aromatic, while in the Rutaceae ill-scented ones are occasionally found. The timbers of *F. australis* and *F. ifflaiana* are noticeably rancid, while those of *F. brayleyana* and *F. laevicarpa* possess pleasant aromas.

[3] Swain (1928) reports that the timbers of *F. pimentiliana* F. v. M. and *F. laevicarpa* C. T. W. possess a reddish hue.

An element of nearly universal occurrence in meliaceous wood is the septate fiber. According to Kribs (1930), fibers of this sort are developed in all members of the large sub-family, Swietenioideae, as well as in the vast majority of those woods included in the sub-family Melioideae. They are wanting, however, in the single genus *Lovoa* of the sub-family Lovoinoideae. Septate fibers have never been observed in woods comprising the Rutaceae, nor do they occur in flindersian timbers.

Structural differences in the wood rays are also diagnostic and offer additional means for differentiating between many woods of these two families. In the Meliaceae, the heterogeneous ray, like the septate fiber is a nearly constant feature of the wood. Rays of this sort occur in all of the woods in the Swietenioideae (Kribs, 1930), and in most of the Melioideae. In fact only four genera belonging to the mahogany family, namely, *Lovoa*, *Ekebergia*, *Walsura*, and *Azadirachta* include woods which possess neither heterogeneous rays nor septate fibers. Where heterogeneity exists, two types of rays are commonly present. The larger and more conspicuous of the two is usually multiseriate and is composed of procumbent cells through the medial portion, and then is tapered above and below to uniseriate margins consisting of one to several rows of upright cells. In woods belonging to the Swietenioideae the marginal upright cells commonly contain crystals. The smaller ray, by contrast, is ordinarily uniseriate and consists entirely of upright cells.

Narrow homogeneous rays feature woods belonging to the Rutaceae, although in several species the marginal ray cells are greatly restricted in length radially across the grain thus resulting in a structure bordering on the heterogeneous type. Marginal cells of this sort are devoid of crystals.

Ripple marks traceable to storied wood rays feature several genera of the Meliaceae. In rutaceous wood they have been observed only in members of the genus *Chloroxylon*. The taxonomic position of this genus, however, is debatable and its inclusion in this family appears to be more or less provisional.

Except in *F. collina* the rays of all flindersian woods examined are homogeneous or merely border on the heterogeneous type in the manner described above, and neither the marginal nor body ray cells contain crystals. The rays of *F. collina*, on the other hand, are strongly heterogeneous, and many of the marginal upright cells are crystalliferous, features exhibited in woods belonging to Swietinioideae of the Meliaceae. None of the ten woods examined has storied wood rays.

Gum canals have been observed in many genera of both families,

hence their occurrence in *Flindersia* is of little diagnostic significance here.

Based upon modern taxonomic concepts *Flindersia* appears to be more closely related to the Rutaceae than to the Meliaceae. From the discussion just completed it is evident that a nearly parallel situation exists when viewed from the standpoint of wood anatomy. Neither the taxonomic nor anatomical characteristics point clearly to either of these two families, but rather appear to combine certain features of both. In conclusion the writer feels that the anatomical evidence gathered during this study lends further support to White's (loc. cit.) views; namely that *Flindersia* should be set up as a separate family, the Flindersiaceae.

SUMMARY

1. In Queensland the timbers produced by the genus *Flindersia* are commonly sold in mixture and thus lose their identity in the trade. In recent years several of them have been used in the United States for cabinet purposes. A systematic study of the wood from 10 of the more important species resulted in obtaining numerous physical and anatomical departures of sufficient magnitude to permit of specific identification.

2. Flindersian wood exhibits physical and anatomical features which are neither wholly rutaceous nor meliaceous, but rather combine several characteristics of the rue and mahogany families, respectively.

3. The formation of a new monotypic family, Flindersiaceae, to receive the genus *Flindersia* is favored by the writer.

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EXPLANATION OF PLATES

PLATE 24

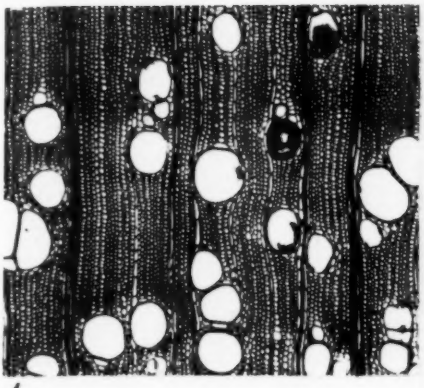
Fig. 1. Transverse section of *Flindersia acuminata*, × 35.
Fig. 2. Tangential section of *Flindersia acuminata*, × 35.
Fig. 3. Transverse section of *Flindersia australis*, × 35.
Fig. 4. Tangential section of *Flindersia australis*, × 35.
Fig. 5. Transverse section of *Flindersia bennettiana*, × 35
Fig. 6. Tangential section of *Flindersia bennettiana*, × 35.

PLATE 25

Fig. 1. Transverse section of *Flindersia bourjotiana*, × 35.
Fig. 2. Tangential section of *Flindersia bourjotiana*, × 35.
Fig. 3. Transverse section of *Flindersia brayleyana*, × 35.
Fig. 4. Tangential section of *Flindersia brayleyana*, × 35.
Fig. 5. Transverse section of *Flindersia collina*, × 35.
Fig. 6. Tangential section of *Flindersia collina*, × 35.

PLATE 26

Fig. 1. Transverse section of *Flindersia ifflaiana*, × 35.
Fig. 2. Transverse section of *Flindersia pubescens*, × 35.
Fig. 3. Transverse section of *Flindersia oxleyana*, × 35.
Fig. 4. Tangential section of *Flindersia oxleyana*, × 35.
Fig. 5. Transverse section of *Flindersia schottiana*, × 35.
Fig. 6. Tangential section of *Flindersia schottiana*, × 35.



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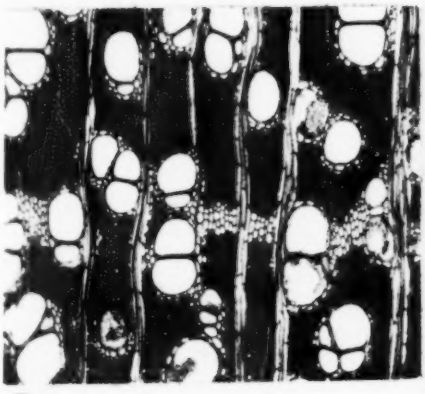

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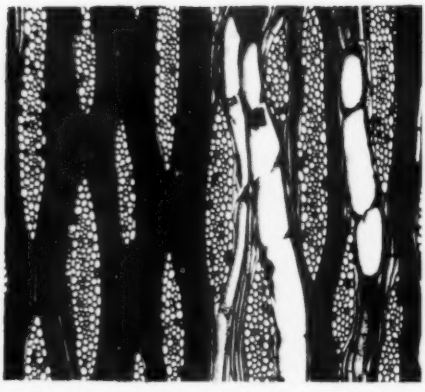

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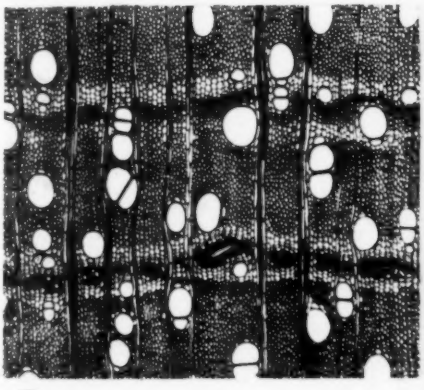

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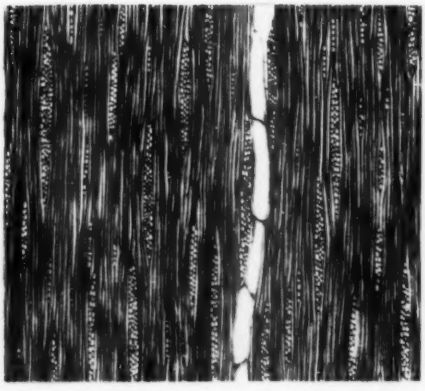

6.

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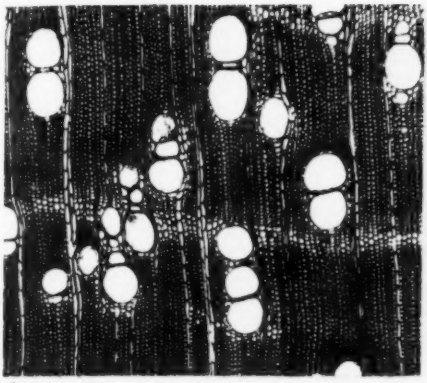
PLATE 25



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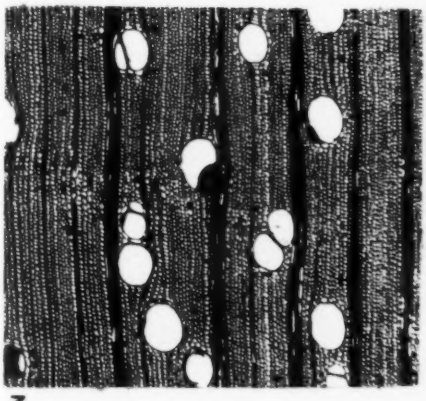

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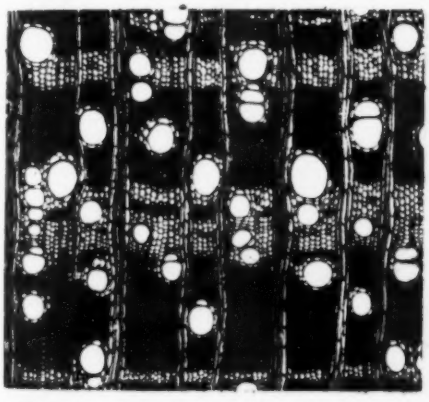

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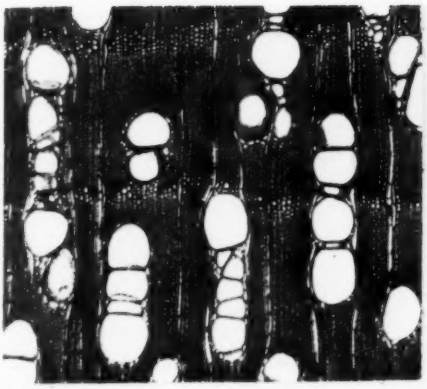
PLATE 26



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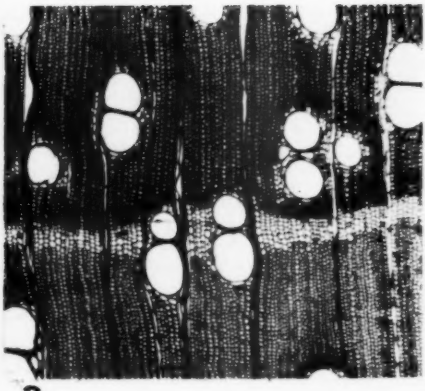

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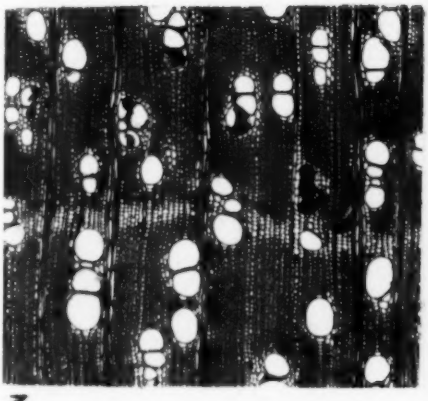

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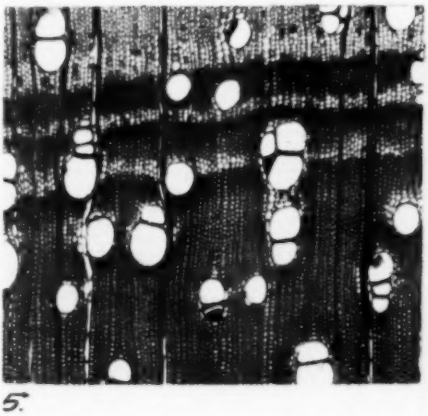

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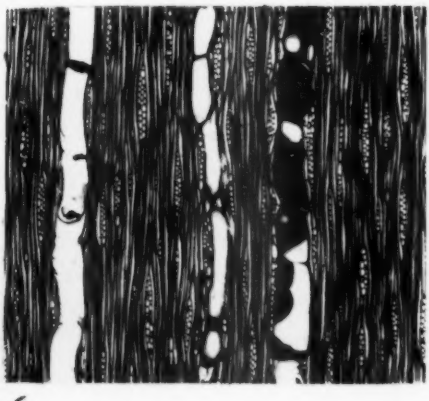

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THE DESTRUCTIVE DISTILLATION OF PEANUT HULLS

By Walker F. Hunter, Jr.[1] and R. W. Bost

INTRODUCTION

Numerous laboratories have attempted to develop processes for the utilization of bulk farm waste products in this country with little success. Of these waste products, perhaps the most logical to utilize are the so-called pentosan waste products, since they are already concentrated in industry. The most outstanding utilization so far has been the development of furfural and furan derivatives by the Quaker Oats Company.

For the work described in this paper peanut hulls were used, although most of the material may apply equally as well to the other products, such as wheat and other grain hulls, corn cobs, and certain straw and stalks of farm waste. Over 70,000 tons of peanut hulls are collected yearly in southern shelling and processing plants. When all these farm products are considered, the waste staggers the imagination. It is true that these products have found many uses to date, but they are always a burden and not an asset to the concern that has them. For fuel they are locally used at the site of production, but due to their bulk, transportation is out of the question. Otherwise, they are supplied to a small local market free or at a minimum cost as substitutes for other cheap products.

Certain researches have been carried out on peanut hulls with little success and no commercial advancement. Though they contain upward of 40% cellulose, it has been found by the U. S. Farm Waste Division to be an uneconomical source of alpha cellulose.[2] This result is due to low yield of alpha cellulose and the drastic and expensive processing that must be applied to free the cellulose from the other constituents of the hulls.[3] Though peanut hulls might lend themselves to the production of furfural as well as oat hulls, no one has seen fit to compete commercially with this source.[4, 5] Fermentation, both anaerobic and

[1] Present address, Eastman Kodak Co., Rochester, N. Y.
[2] Anon., Chem. and Met. Eng., **37:** 417 (1930).
[3] Lynch and Goss, Ind. and Eng. Chem., **22:** 903 (1930).
[4] Hall, Slater, and Acree, Bur. Standards J. Research, **4:** 329 (1930).
[5] Bryner, Christensen and Fulmer, Ind. and Eng. Chem., **28:** 206 (1936).

aerobic, has been investigated but low yields were obtained, due, it is believed, to the inhibiting action of the lignin present.[6]

It appears, today, that wood distillation from a commercial point of view is rapidly losing its prestige. The economic condition of this industry is largely due to competition from synthetic chemicals and also to the increased cost of purifying the products distilled from wood. If the cost of raw material could be lowered and technical advance could be made in the industry, destructive distillation might obtain a better footing economically. This research was instigated to determine the relationship between the products of distillation from pentosan waste products such as peanut hulls and those from wood; any difference being due to plant structure and pentosan content.[7, 8, 9] If any appreciable difference were found, the economic status of these waste products might allow this type of utilization.

EXPERIMENTAL

The distillation was carried out in a cylindrical iron retort which was electrically heated from the outside by four 550-watt heating coils. The furnace was $2\frac{1}{2}$ inches in diameter by 18 inches long, inside dimensions, and insulated by a steel jacket containing $2\frac{1}{4}$ inches of magnesium-asbestos cement. Untreated hulls were introduced at one end of the core by removing an iron plate which was held against a half union by four $\frac{1}{2}$-inch bolts. The whole was made air-tight by a copper-asbestos gasket between this iron plate and the half union connected to the core. The distillate was carried off by a $\frac{1}{4}$-inch iron pipe connected through a pipe cap screwed to the other end of the core. With this apparatus it was possible to reach a red heat of iron within one hour, though more time was utilized in the process of distillation. The heating was continued until nothing more distilled over. Usually two or three hours' heating was required for each distillation.

The products distilled can be divided into three fractions by their physical properties. The gases were inflammable and contained carbon monoxide, carbon dioxide, hydrogen, and low molecular weight organic compounds. The liquid distillate was miscible with water, contained varied organic compounds to be discussed later, and large quantities of

[6] Fred, Peterson, and Anderson, Ind. and Eng. Chem., **15**: 126 (1923).

[7] Fraps, Am. Chem. J., **25**: 26 (1901).

[8] *Wood Distillation*, by L. F. Hawley, Chem. Cat. Co. (1923).

[9] The Pyrolysis of Carbon Compounds, by Charles Dewitt Hurd, Chem. Cat. Co. (1929).

water. The semi-solid portion which was immiscible with water and the water fraction, was colored a light yellow but darkened on standing. This color change occurred in the presence or absence of light and air. Also further tar was formed from the water fraction on standing. The

TABLE I

Compounds identified in pyroligneous acid

COMPOUND	DERIVATIVE	MELTING POINT	REMARKS
		°C.	
Acetone	2-4 dinitrophenylhydrazone	127	Mixed M.P. 127°C.
Ethyl n-propyl ketone	2-4 dinitrophenylhydrazone	130	Does not give test for aldehydes. Proven by mixed melting points not to be acetone or methyl n-propyl ketone
Methyl n-butyl ketone	2-4 dinitrophenylhydrazone	110.5	Mixed M.P. 110.5°C.
Formic acid (solution)	No derivative. Quantity and dilution prohibited further treatment	Reduced $KMnO_4$ but does not give aldehyde test with Schiff's reagent, Fehling solution, or Benedict's solution. Precipitates HgCl from $HgCl_2$ solution on heating. Solution regenerated from Ca salt and must be an acid	
Acetic acid	p-nitro benzyl acetate	77.8	Typical odor and proved to be acid. Mixed M.P. 77.8°C.
Ethyl alcohol	3-5 dinitrobenzoate of ethyl alcohol	92	Mixed M.P. 92°C.
Butyric acid esters	No derivative. Quantity too small	NaOH saponification—acidification with H_2SO_4 gave unmistakable odor of acid	

material used for further analysis was a composite of distillates, except gases, of many distillations. The carbon residue remaining in the furnace was quite finely divided and could easily be ground in a mortar to such a degree of fineness that colloidal solutions of the carbon would

TABLE II

Compounds indicated in pyroligneous acid

	REMARKS
Methyl Alcohol	Due to small volume of pure material, a pure derivative could not be obtained. Its odor and boiling point indicated the presence of methyl alcohol and by reactions the fraction was proved to be an alcohol
Allyl Alcohol	Dilute water solution. Reduced $KMNO_4$ and bromine in CCl_4. Derivative was impure and reactions were not positive enough to be considered proper proof of the presence of allyl alcohol
sec-Butyl Alcohol	Dilute water-alcohol fraction, impure. No derivative. Water solution gave iodoform test. This is quite indicative after elimination of other compounds which give iodoform under these conditions, but is not considered definite enough to be conclusive

TABLE III

Data on higher boiling fractions

FRACTION	LITMUS	SOLUBILITY IN WATER	COLOR WITH $FeCl_3$	SCHIFF'S	2-4 DINITROPHENYL HYDRAZINE	NITROGEN	BOILING POINT
							°C.
5	Acid	Slight	Brown	Neg.	Neg.	Neg.	106–118
6	Acid	Slight	Reddish brown	Pos.	Neg.	Neg.	146–150
7	Acid	Slight	Reddish brown	Pos.	Pos.	Neg.	150–155
8	Acid	Slight	Reddish brown	Pos.	Neg.	Neg.	157–160
9	Acid	Neg.	Dull brown	Pos.	Neg.	Pos.	160–190
10	Acid (weak)	Neg.	Brown	Pos.	Neg.	Pos.	198–205
11	Acid (weak)	Neg.	Brown	Pos.	Neg.	Pos.	205–210
12	Acid (weak)	Neg.	Brown	Neg.	Neg.	Pos.	212–200
13	Acid (weak)	Neg.	Brownish black	Neg.	Neg.	Pos.	220–225

result when it was treated with water. No significant work was done on the carbon. This will be studied later.

The pyroligneous acid or water fraction was treated with lime to

remove the acids and then subjected to fractional distillation. The methyl ketones were then separated by sodium bisulfite. By thus separating this fraction of the distillate, some identifications have been made, as shown in Table I. Due to the large excess of water, the number of products, and the limited quantity of material at hand, many compounds that were evidently present were not definitely proved as constituents of the distillate. However, the results from the physical properties and chemical reactions have rather definitely proved that the products were quite similar to the products of wood distillation, if not somewhat more complex. The evidence concerning the presence of some other compounds not definitely proved to be present is discussed in Table II.

Termination of the research left the oil fractions without identifications. However, the oils were fractionated and many reactions determined. This oil contains fractions which boil between 100°C and 225°C. Together with these boiling points are given some of the properties of the individual fractions of this oil, Table III.

The tar product was a plastic solid at ordinary temperatures and contained small amounts of carbon. Since no indications of aldehydes were found throughout the work, it is logical to conclude that the tar is formed from these compounds and phenols, along with other polymerized and high boiling products.

CONCLUSIONS

This mode of destructive distillation resulted in products little different from those derived by destructive distillation of wood. The bulk of this type waste product will also be an inhibiting factor in this method of utilization. The work as a whole has shown that the products are identical in physical properties with those from wood distillation, that their chemical content is approximately the same, and that such a process would inherit all the difficulties known in this industry today. These difficulties center themselves in the complexity of the materials obtained. Under our present economic status of synthetic chemistry, petroleum, and coal, this type of process has little chance of existence. In case of a shortage of coal or petroleum, this material can be utilized as a source to obtain similar products as substitutes. The research program has indicated other possible avenues for utilization of these products but opportunity to follow them up has not arisen.

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ACHLYA FLAGELLATA AS A FISH PARASITE

By Wesley N. Tiffney and Fred T. Wolf

In the spring of 1935 the senior author observed in a small pond near Lexington, Massachusetts, a considerable number of newts infected with a fungous disease. The host was identified as *Triturus viridescens*. Specimens were brought into the laboratory, and two species of fungi, *Saprolegnia parasitica* Coker and *Achlya flagellata* Coker,[1] were isolated from a number of them. The presence of both species of fungi on the infected animals was furthermore verified by direct examination. Inasmuch as *Achlya flagellata* occurred in connection with *Saprolegnia parasitica*, which is known to be a severe parasite, while *Achlya flagellata* has apparently never been reported in the literature as a parasite, little significance was attached at that time to the isolation of the latter species from infected animals.

The second isolation of *Achlya flagellata* from diseased animals occurred in the autumn of 1935. Specimens of *Lebistes reticulatus* had been secured and kept in a 25-gallon aquarium tank in water from the Cambridge, Massachusetts, municipal supply. These fish were intended for use in a study which was being made of some physiological aspects of parasitism by *Saprolegnia parasitica*. After about eight weeks in the aquarium tank, twelve of the seventy fish were observed to be infected by a fungus which was identified as *Achlya flagellata*. No other species of water mold was present, although large masses of bacteria appeared about the infected areas on the fish. From experience gained in studying the etiology of the *Saprolegnia parasitica* fish disease, the senior author believes that bacteria, which usually are not fatal to the fish, should be regarded as secondary invaders. All the fish infected by the fungus died.

Achlya flagellata was isolated from the diseased specimens of *Lebistes reticulatus* and grown on hemp seed in sterile distilled water; the bacteria-free culture was used to inoculate *Fundulus heteroclitus* in an attempt to verify the ability of the fungus to act as a parasite and to determine whether injury to the host had any effect on the incidence of

[1] Coker, W. C. 1923. The Saprolegniaceae with notes on other water molds. 116–118, pl. 37. Univ. of N. C. Press, Chapel Hill.

infection. The 60 fish used in this experiment were divided into three groups as follows: Group I consisted of 25 fish which were injured slightly by the removal of a few scales, Group II consisted of 25 uninjured fish, and Group III included 10 fish, of which 5 were injured and 5 uninjured. Each group was placed in a separate tank. All tanks received water from the same source, and were maintained under identical conditions of temperature, light, and aeration. Groups I and II were exposed to zoöspores of *Achlya flagellata*, while Group III, which was not exposed to the fungus, served as a control. Of the 25 injured fish in Group I, 9 were attacked by the fungus and died. In no case did infection result in the uninjured fish (Group II) or the controls (Group III). This experiment apparently places *Achlya flagellata* in the category of wound parasites.

During the early summer of 1936, *Achlya flagellata* occasioned severe losses in the Bayfield, Wisconsin, hatchery of the state Department of Conservation. According to Mr. B. O. Webster, Superintendent of Fisheries, who provided much of the information concerning the epidemic, there had been no history of outbreaks of fungus disease at the Bayfield hatchery in past years, nor did the disease occur to the extent of economic importance in other hatcheries in Wisconsin during 1936.

At the Bayfield hatchery, about 3,000,000 fingerlings of brook trout, *Salvelinus fontinalis;* rainbow trout, *Salmo irideus*; and brown trout, *Salmo fario*, were raised in metal tanks measuring three feet by fourteen feet by eight inches. The water used comes from two sources; the first is an artesian well, and the second is a creek called Birch Run. No infection occurred in the tanks supplied with water from the former source. For this reason, after the epidemic had become established, water from the artesian well was used in all of the tanks, and common salt was used liberally in an attempt to control the disease, but these measures were applied too late to be of much value.

The first cases of infection appeared late in May. On May 29, Dr. E. M. Gilbert collected samples of water from the tanks, masses of fish food overgrown with the fungus, and infected fish. Hemp seed cultures made from these collections by the junior author showed that *Achlya flagellata* was the cause of the disease; no other fungi were involved. Dr. J. N. Couch kindly identified the fungus from subcultures from the infected fish.

It was found that great differences were displayed by the three species of trout in regard to resistance to infection by the fungus. Fingerlings of brown trout, *Salmo fario*, and rainbow trout, *Salmo irideus*, appeared

to be almost immune to the disease. With brook trout, *Salvelinus fontinalis*, however, about 50 per cent of the fingerlings, representing about 500,000 fish, were killed. The percentage of infection was slightly larger than this figure would indicate, as some of the infected fish recovered. Although the disease was most severe in its attack upon the fingerlings, larger fish were also infected with the fungus and killed. The epidemic ran its course, and was well under control by the middle of July.

It appears, therefore, that *Achlya flagellata* may at times become a serious parasite of fish under Wisconsin conditions. In Massachusetts, on the other hand, the senior author has encountered it only twice within a period of three and a half years in a series of 128 isolations of fungi from diseased fish found under natural conditions. The details of these two collections have been given above. It would appear that *Saprolegnia parasitica*, found 122 times, is the predominant parasitic form in that region, and that *Achlya flagellata*, although interestingly enough capable of parasitism, is of little importance there.

The work of the senior author was carried out in the Laboratories of Cryptogamic Botany of Harvard University, under the direction of Dr. W. H. Weston, Jr., while that of the junior writer was done in the Department of Botany, University of Wisconsin, and supported by a grant from the Alumni Research Foundation. To the various persons who have been of assistance in this investigation, the writers wish to express their appreciation.

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THE FORMATION AND OPERATION OF THE TRAPS IN THE NEMATODE-CATCHING FUNGUS, DACTYLELLA BEMBICODES DRECHSLER

By JOHN N. COUCH

PLATE 27

The recent papers by Drechsler (1933, 1937) have greatly added to our knowledge of the nematode-catching fungi and to an understanding of the means by which the nematodes are trapped. No experimental observations, however, have been reported which describe the conditions under which the traps are formed or how they close or the stimuli which may cause their closure. Is the formation of the traps conditioned by the presence of nematodes? Do the traps close instantaneously or slowly? Is closure brought about by a mechanical or chemical stimulus? The chief objects of this investgation have been to discover the conditions which determine the formation of the nematode traps in *Dactylella bembicodes* and how they operate in catching the nematodes.

The present fungus was found growing over a small piece of decorticated, semi-decayed, pine wood on which there had been some *Dacryomyces* material. It was first recognized under the binocular microscope by the tiny, upright, solitary conidiophores. Upon mounting some of the mycelium, numbers of nematodes, some living, others dead, were found attached to the fungus by small traps.

STRUCTURE OF FUNGUS

The fungus produces a rather scanty growth on the wet wood, but a heavy mycelial growth is formed on certain nutrient agars. The threads are rather straight, branched, frequently septate, 3.8–4.6μ thick, with a considerable number of the H type of anastomoses. Conidiophores borne abundantly in most cultures, thick at base, about 2.8–3.5μ thick near tip and 400–1500μ tall, with one apical spore. The spore when mature is cut off from the stalk and may either fall off or be carried away by air currents. Spores ovoid, bluntly pointed at both ends, thickest in the distal part of the middle region, four-celled with a small distal, two small proximal, and a large central cell, in which

is a large, glistening globule of material. When growing on moist wood or in aqueous solutions with nematodes, the fungus forms numerous small rings or loops; rings are also produced on certain kinds of nutrient agars, and when the food material is reduced. Each loop consists of three cells and is attached to the hypha by a short, two-celled stalk. In the formation of the loop the last loop-cell anastomoses with the top stalk-cell and also with the first loop-cell. Loops 24–31μ outside diameter, 16–21μ inside diameter. The spores germinate readily, producing a germ tube of even diameter about 3.6–4μ thick. Most commonly a germ tube arises from each end of the spore, growing out straight in a line parallel to the long axis of the spore. Sometimes a germ tube may arise from the small cell next to the end cell, the tube growing out at about right angles to the spore. When the spores germinate in a liquid medium containing nematodes, three or four rings are formed on the germ tube before it has attained a length of 300μ.

Some preliminary observations were made to determine how the rings functioned in catching the nematodes. Some fungal threads bearing rings were isolated on a slide in water with several nematodes and it was possible under the binocular in a few instances to maneuver the nematodes into the loops. Because of the low magnification, however, it was impossible under the binocular to discover how the trap worked and, in every instance observed, before the mount could be transferred to the compound microscope the traps had completely closed and the nematodes were held fast. Moreover it was impossible to observe the traps under the compound microscope with the fungus growing over the surface of the wood.

To overcome these difficulties the fungus and nematodes were cultured in nutrient agar.

ISOLATION OF NEMATODES IN CULTURE

In culturing the nematodes the technique described by Chandler (1924) was used at first. Chandler used "ordinary nutrient agar" with a drop or two of dirty water to supply bacterial growth. Dirty water, however, almost invariably contains the spores of various fungi the growth of which renders such cultures worthless. Therefore maltose peptone agar plates inoculated with one or more species of bacteria from pure cultures were tried on which to culture the nematodes. The nematodes grew well for several days and then died out, perhaps due to the accumulation of waste products in the agar. After some further experimentation it was found that by adding some living cells of the green

alga, *Chlorella*,[1] to the bacterial inoculation the nematodes multiplied abundantly and remained healthy and active for weeks or until the agar culture dried up.

ISOLATION OF FUNGUS IN PURE CULTURE

The fungus was easily obtained in pure culture since the spores are large and germinate readily on nutrient agar. A place on the original culture on wood where the conidiophores stood out distinctly and were free from trash was located under the binocular microscope. With a needle to which was attached a small block of agar, a single spore could be picked up by touching the spore to the surface of the agar. The little block of agar to which the spore was attached was transferred to a sterile maltose-peptone agar plate or tube.

EXPERIMENTS TO INDUCE THE FORMATION OF RINGS

The fungus grew slowly on maltose-peptone agar No. 5, the largest colonies attaining a diameter of 15 mm. after ten days. However, on the maltose peptone agar no rings were formed. Since numerous rings were formed when the fungus was growing over the surface of wood, it was suspected that the wood might contain something which induced their formation. The fungus was then grown in a sterile hay decoction but no rings were formed. However, a drop of the brownish water from the original dish containing nematodes and fungus placed on the edge of the mycelium on maltose peptone agar caused the formation of numerous rings in that region after twenty-four hours. The water in the original culture was tested and found to be acid. Suspecting that the acidity of the medium might influence the formation of the rings, cultures of the fungus were made on maltose peptone agar to which were added varying amounts of H_3PO_4 with results as indicated in the accompanying table. The cultures were observed occasionally during a period of two weeks.

1. 0.1 cc. of 0.1N H_3PO_4 in 20 cc. agar No. 5	No rings
2. 0.2 cc. of 0.1N H_3PO_4 in 20 cc. agar No. 5	No rings
3. 0.5 cc. of 0.1N H_3PO_4 in 20 cc. agar No. 5	No rings
4. 1 cc. of 0.1N H_3PO_4 in 20 cc. agar No. 5	Many rings
5. 2 cc. of 0.1N H_3PO_4 in 20 cc. agar No. 5	Many rings
6. 3 cc. of 0.1N H_3PO_4 in 20 cc. agar No. 5	Many rings

[1] Cultures of *Chlorella* have been kept going in the laboratory for several years on Bristol-Roach agar (see Ann. Bot. **40**: 149. 1926).

This experiment indicated that by acidifying the culture media to a certain degree the fungus could be induced to form many rings. The rings are formed only on the hyphae which grow on the surface of the media and stand upright with their faces at right angles to the hyphae from which they arise. In later experiments it was found that growth was about twice as luxuriant and the production of rings more abundant on Blakeslee's No. 230 agar than on acidulated maltose peptone No. 5. On potato dextrose agar (Chamberlain, *Methods in Plant Histology*) growth was about twice as luxuriant as on No. 230 but no rings were formed.

Also it has been noticed that the production of rings is greatly increased as the available food supply in the culture media is reduced. The production of rings occurs on agar No. 230 but when the mycelium reaches the edge of the dish or when a groove is cut in the surface of the agar at the edge of the growing region, the number of rings is greatly increased. Furthermore when several inoculations are made on the same culture dish and the mycelium grows together the same increase in ring production occurs. It thus appears that the traps may be formed as a response to a reduced food supply.

OBSERVATIONS TO DETERMINE HOW THE TRAPS WORK

With the fungus in pure culture producing abundant rings and with plenty of nematodes also at hand, it was possible to carry out some experiments to see how the rings work.

The following observation was made to determine if the rings or traps close instantaneously or if they close by a slow swelling (i.e. taking a few seconds to close) of the three cells. This observation had been impossible before with the fungus growing on wood where observations with a compound microscope were worthless. Agar teeming with nematodes was scraped off and placed on the center of a fungus culture on which there were numerous rings. The following morning, about twelve hours later, the colony was observed. Many nematodes had wriggled from the central mass of agar and were crawling about over the surface of the agar over and among the fungal hyphae. Many nematodes had already been caught in the traps. Some were still actively wriggling in a futile effort to free themselves, others had already been killed and their bodies invaded by the fungus. Attention was concentrated on one active, free nematode gliding sinuously about among several rings. For a while it would move rapidly forward or again it would stop and thrust its head forward first in one direction, then in another. After a time the nematode thrust its head into one of

the rings, upon which the three component cells of the ring immediately swelled gripping the worm so firmly that it could neither move forwards nor backwards. It did squirm violently, however, in a futile effort to free itself. Once the nematode is caught in the trap its death is certain, for in no instance has one been observed which was able to free itself. Using the above technique a number of nematodes have been observed to enter the rings and in all cases when the worms are caught the action of the trap is instantaneous.

In some instances all the nematodes may be caught in the traps. Usually, however, some of the nematodes miss the traps and crawl out on the clean agar carrying bacteria with them. These will lay eggs in the agar so that new nemas will be coming on. Meanwhile the bacteria and *Chlorella* multiply, the former to furnish food for the nemas. The fungus continues to grow and form new rings which in turn trap some of the new nemas. Such cultures consisting of the fungus forming rings, the nemas, bacteria, and *Chlorella* may keep going for several days. As a rule in such cultures the bacteria get the upper hand, the fungus overrun by bacteria stops growing and the rings lose their ability to function. In such old cultures, upon several occasions, I have observed a nematode crawl through a ring and even stop and loiter in it for several minutes with impunity. The rings appeared perfectly normal but for some reason had lost their ability to close.

If the nematodes are slow to enter the rings, it is possible to hasten the process by pushing them with needles, using a high powered binocular dissecting microscope. The nema shown in figure 16 was pushed into position and entered the loop (a), the cells of which swelled immediately holding the nema fast. The thread (t) to which this loop was attached was then cut leaving a long end in front. Then by holding the thread (t) on a needle the nema was pulled over the agar and its head slipped into another loop (b). In spite of the fact that the nema was still alive and vigorous this ring failed to swell even after an hour. Meanwhile the nema's tail end was threaded into a third loop (c) which, however, also failed to close. It is very likely that the loops (b) and (c) were injured in manipulation, for numbers of cases have been seen where a nematode was caught by two loops arising from the same or from different hyphae.

EXPERIMENTS TO DETERMINE WHAT CAUSES THE LOOPS TO SWELL

Having observed that the nematodes were caught by the instantaneous swelling of the three loop cells thus closing the loop, it seemed of great interest to discover what caused the cells to swell.

The vigorous action of the nematodes suggested the idea that the closure of the trap might be due to the mechanical irritation brought about by the vigorous movements of the nematode's body. To test this theory a fine glass rod was inserted into a loop under a high power binocular dissecting microscope and the rod moved back and forth in the loop, simulating as much as possible the movements of a nematode. Later the same experiment was performed several times with a Fitz microdissection apparatus but in no case could any more than a slight swelling be obtained (fig. 10). It was apparent from these experiments that mechanical irritation plays a very small, if any, part in the closure of the loops.

The above experiments were made before I had seen one of the traps close on a nematode under the compound microscope. Here one can see that the violent movement of the nematode takes place after it is caught, not while it is being caught, for that occurs instantaneously. It seemed likely, therefore, that the stimulus causing the closure of the traps might be of a chemical nature. Accordingly weak solutions of ammonia, potassium hydrate, phosphoric acid, acetic acid, hydrochloric acid, sulphuric acid, and lactic acid were applied to the loops. Treated with a 1% solution of lactic acid the loops were caused to swell slightly but in none of the experiments could complete closure be obtained. These experiments were inconclusive, failing to show positively that the closure of the traps was due to chemical stimulus.

That the closure of the traps is due to a chemical (as opposed to mechanical) stimulus was discovered accidentally and in a very roundabout way. It was noticed on many occasions that when blocks of agar with hyphae were cut from the pure culture the loops near the cut edges were always swollen. It was suspected at first that cutting the hyphae to which the loops were attached might permit a sudden intake of water and the consequent swelling of the loops. However, upon cutting some hyphae isolated on a slide in a block of agar the loops all remained unswollen regardless of how badly the hyphae to which they were attached were mutilated. It then occurred to me that I was using a cold scalpel whereas a hot one was invariably used to cut the blocks from the stock cultures. Could heat cause the cells to swell and the traps to close? To answer this a block of agar with threads on which were many loops was cut from the stock culture, placed on a slide and a hot scalpel held about two millimeters above the surface for about two seconds. The loops were then examined under the microscope and all of them excepting a few were completely closed (as in fig. 9). Indeed it was possible

to locate several loops under the low power of the microscope and watch them close by having some one wave a hot needle over the loops. Such experiments have been repeated many times with the same results. It is interesting to note that only the three cells of the loop swell; the cells of the hyphae and the spores are not visibly affected by the heat.

To determine how much heat was necessary to cause the swelling, warm, distilled water was dropped on the loops. It was found that water at any temperature from 33°C.–75°C. would cause the loops to close. Below about 30°C. there was no swelling and above about 80°C. the cells failed to swell being killed by the heat.

An examination of the cells which have been caused to swell by dry heat or warm water shows that the three swollen cells contain a refractive substance which is doubtless gelatinous or colloidal in nature. The closure of the trap is due to the sudden swelling of this substance. The heat doubtless "activates" the colloids causing them to swell. This swelling may be due to a rearrangement of the molecules of water and colloidal material already in the cell or it might be that additional water is imbibed from the stalk and thread cells. The rapidity of the reaction would seem to favor the first view.

The closure of the traps by heat does not throw much light on how the nematodes caused their closure. It is assumed that the temperature of the nematode's body is that of other cold blooded animals and therefore it is certainly not the "heat" of the nematodes' body that throws the trap. It can hardly be doubted, however, that the nematode gives off some substance which diffuses into the loop cells causing the swelling and the consequent closing of the trap.

After a nematode is caught in a trap its body is rapidly invaded and filled by the fungal hyphae with the consequent consumption of the nematode as food by the fungus. New hyphae sprout out from the parasitized nema's body and extend out over the substratum giving rise to more traps and one or more conidiophores.

Since the fungus grows readily in artificial culture, producing abundant spores, it is possible that the spores might be mixed with soil and broadcast over small areas of nematode infested soil with the consequent control of the nematodes (see Linford, 1937).

SUMMARY

A fungus that catches nematodes is described. The fungus has been isolated in pure culture and grown on a variety of media. It has been found that the nematode traps are produced when the fungus is grown

on acid media. Also a reduction in the food supply induces the formation of rings, as when the fungus reaches the edge of the culture dish or when a groove is cut in the agar at the edge of the growing region. On certain culture media, e.g. potato dextrose agar, the rings are not formed at all.

The nematodes have also been isolated and grown in culture on agar. To furnish food for the nematodes the agar plates were inoculated from pure cultures of bacteria. The addition of the green alga, *Chlorella*, to the cultures of nematodes keeps the cultures in a healthy condition for a longer time.

The closure of the rings has been observed under the compound microscope. When a nematode thrusts its head or tail into one of the rings it closes practically instantaneously by the simultaneous swelling of the three cells of the ring.

Partial closure of the rings may be induced by mechanical irritation of the ring as when a fine glass rod is inserted and moved back and forth in the loop. Also slight closure may be induced in a few rings by a 1% lactic acid solution. Numerous other dilutions of acids and alkalies failed to cause any swelling. Complete and instantaneous closure may be induced by the application of heat, either dry heat or warm water or steam. Using warm distilled water it was found that a drop or two of water of any temperature from 33°C to 75°C applied to rings caused instantaneous and complete closure. In such experiments only the cells of the rings swell, the threads being unaffected. Water above 80°C failed to cause swelling, the high temperature killing the cells and perhaps inactivating the colloids. A microscopic examination of the swollen loop cells showed that they contained a refractive gelatinous looking substance, the substance doubtless which had been caused to swell.

The experiments with heat demonstrate that the swelling may be initiated by a stimulus such as heat but at present it is impossible to see the relation between the closure of the traps by heat and by the "cold blooded" nematodes. It is assumed that the living nematodes give off a chemical substance which induces the swelling of the colloids just as heat induces their swelling.

After the nematode has been caught, the fungal hyphae invade and destroy the animal's body, using it as food.

The suggestion of biological control of soil nematodes by the fungus is given.

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EXPLANATION OF PLATE 27

Fig. 1. Diagrammatic habit sketch of fungus growing over a damp piece of decayed pine wood, showing fungal threads (f.t.) on which are formed the rings (r) which catch the nematodes (nc), also conidiophores (c) on which the spores (s) are formed. × 50.

Figs. 2–5. Germinating spores. In fig. 5 the hyphae floating on the surface of water have formed several nematode traps one of which has caught a nematode. × 110.

Figs. 6–11. Formation and structure of fungal rings.

Fig. 6. Lateral branch growing out, the tip curving back, as it grows to fuse eventually with the upper stalk cell (fig. 8, a) and the first loop cell (fig. 8, b). Figs. 7 & 8. Edge and side views of mature loops. Fig. 9. A loop the three cells of which have expanded throwing the trap without catching a nematode. Fig. 10. A loop into which was inserted a glass needle, by the vigorous movements of which one of the cells was caused to swell. Fig. 11. One of several loops treated with 1% lactic acid. All × 525.

Fig. 12. Above, the anterior, below, the posterior part of a trapped nematode, the body of which has been invaded by fungal hyphae. × 580.

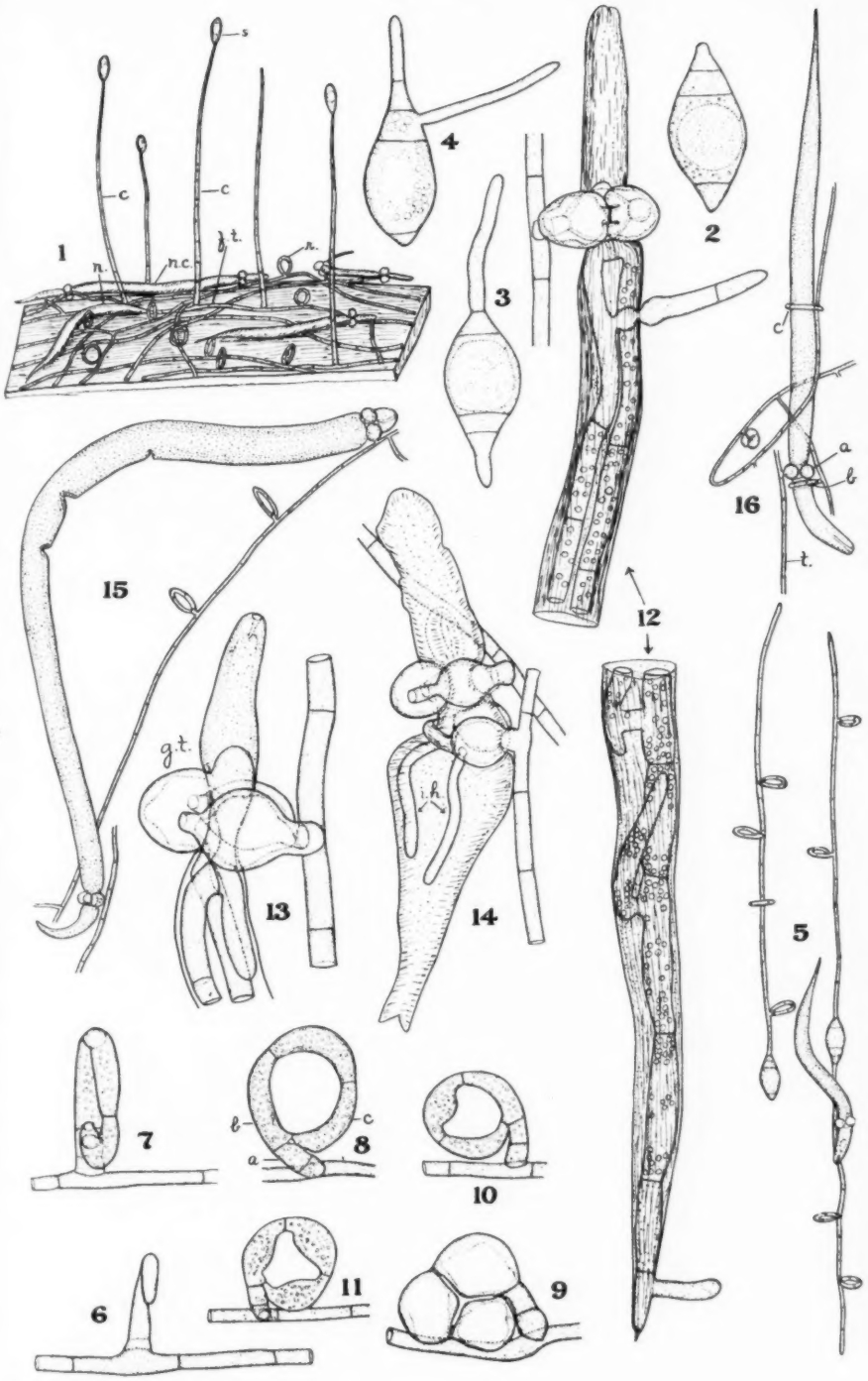
Fig. 13. Germ tube (g.t.) from one of loop cells penetrating body wall of nematode to form the invading hyphae. × 930.

Fig. 14. Large rotifer trapped and invaded by fungus. i.h. infecting hyphae. × 525.

Fig. 15. Large nematode trapped by both head and tail ends. This worm's body was completely filled with fungal hyphae. × 110.

Fig. 16. Nema shown was maneuvered into loop (a), i.e. pushed into position and entered loop itself, the cells of which immediately swelled holding nema fast. See text for further explanation. × 110.

PLATE 27



ADDITIONS, CORRECTIONS, AND DELETIONS FOR THE FLORA OF THE TRYON REGION

By Donald Culross Peattie

In the spring of 1919 I began the study of the flora of the Tryon region of Polk County, North Carolina, and some adjacent regions, chiefly mountainous, in South Carolina. After collecting many hundreds of specimens I began to search the leading herbaria for previous collections from this region and entered into correspondence with other collectors. Some were kind enough to make at my request special collections of interesting genera when they went to the Tryon country. The results were finally embodied in a series of papers entitled "Flora of the Tryon Region of North and South Carolina: An annotated list of the plants growing spontaneously in Polk County, North Carolina, and adjacent parts of South Carolina, in Greenville and Spartanburg counties." It appeared in six parts, running in the Journal of the Elisha Mitchell Scientific Society (Chapel Hill, N. C.) from September, 1928, to June, 1931 (vols. **44–46**).

Between 1926 and 1936 I did not revisit this region, but in that time a few species were added to the flora by other collectors, notably Miss N. B. Kimber who found additional species of *Asarum*, *Phlox*, and *Asplenium* and Mr. B. E. Smith who added two dodders to the known flora. Notable, too, was the rediscovery on the north side of Tryon Mt.* of the Rocky Mountain *Woodsia* by Dr. Edgar T. Wherry. *Woodsia scopulina* had first been found in this state in 1897 at that locality by E. C. Townsend, but had never since been located.

The spring flora of the Appalachians is well known, owing to its beauty and the number of visitors who come at that delightful time of year, but little attention is usually paid to the autumn flora, which bristles with the technical difficulties of asters and goldenrods and other composites. It was with great interest, therefore, that in September of 1936 I took a house in the country outside the town of Tryon and prepared to see what could be added to the known list of 1076 vascular plants. Diligent collecting was all that was needed to add many autum-

* Called White Oak Mountain in Wherry's note (Amer. Fern Journal **24**: 101. 1934). Ed.

nal Compositae. But more surprising were the following additions which are also, I believe, new to western North Carolina: the waterweed, *Anacharis densa;* the African grass, *Eulalia viminea; Trillium declinatum;* a Louisiana violet, *Viola Lovelliana;* and, most astonishingly, the salt marsh shrubby composite, *Baccharis halimifolia.*

I wish to acknowledge gratefully the assistance, in the naming of many of my collections, of Mrs. Agnes Chase, who identified the grasses, Dr. Edward Palmer who named the woody plants, Dr. N. C. Fasset, who examined all aquatics, Dr. S. F. Blake who identified the Compositae, and Dr. John K. Small who named several miscellaneous species that were puzzling. My specimens have all been sent to the herbarium at the University of North Carolina, except for the woody plants, which remain at the Arnold Arboretum. My collections extended from Sept. 28, 1936, to May 16, 1937. Most of the new species were, naturally, autumnal, yet the spring flora yielded thirteen species, including three species of the difficult brambles.

It is my pleasure, also, to acknowledge that certain species new to the flora were drawn to my attention by resident amateurs. Mrs. George Holmes showed me where the checkerberry, *Gaultheria procumbens,* grows on Godshaw Hill, apparently the only locality in the county. Miss Helen Stearns, in her garden, showed me the handsome clubmoss, *Lycopodium complanatum,* which she had brought down from Melrose Mt. And Mr. William Weigel, an enthusiastic wildflower gardener, has transplanted to his plot the monkshood, *Aconitum uncinatum,* and the old favorite, lily-of-the-valley, which grows wild on Rocky Spur, in Greenville Co., S. C. Native to Europe and the mountains of Asia, this is also an inhabitant, as an indigene, of the southern Appalachians, but it was new to the recorded flora of the Tryon Region.

A special study was made of *Asarum,* a genus which reaches its highest development in the southeastern states, in order to test the validity of the many species that have been proposed and often all too loosely described. With the exception of *Asarum Memmingeri* which was not found this time, all the species hitherto reported from this region were located again, collected in quantity and very carefully studied. It is the conclusion of this writer that they are better founded than one would judge from the descriptions of them in books.

It was a pleasure also to be able to add two species and one new variety to the recorded trilliums of the region. Several trees and shrubs were also newly discovered, giving this county one of the longest and most interesting lists of woody plants in the state.

The present writer is now leaving for a few years in the West. He hopes that others will investigate the peculiarly rich flora of this region where the piedmont meets the front wall of the Blue Ridge and so many diverse elements are met together. Further collection should certainly greatly increase the number of grasses and sedges. The mountains in the northwestern corner of the county have never been botanically investigated by anyone, so far as I know. The extreme eastern edge of the county has only been entered by a botanist on a single occasion. The size of the "unknown" area cannot, of course, be taken as a measure of the possible "unknown" plants, since the well-known regions sufficiently resemble the little-known in their vegetation to make it likely that the present number of some 1155 species of flowering plants and ferns could not be increased by much more than another hundred species. Most of these will undoubtedly be found among the highly technical groups.

ADDITIONS

FERNS

Asplenium pinnatifidum Nutt. (Spleenwort)

This interesting little plant, which so much resembles the walking fern, has been found on cliffs and rocks in Greenville Co., S. C. Specimens: Hogback Mt., Feb. 12, 1930, and Clarke's Mt., March 2, 1930 (Miss Kimber).

Selaginella apus (L.) Spring.

Much resembling a moss, this little fern ally appears to be quite common on wet rocks near waterfalls and brooks. I found it in quantity in Vaughan's Glen. Specimen: Dec. 1, 1936. No. TR19.

Lycopodium complanatum L. (Trailing Christmas Green)

This handsome little plant grows on Melrose Mt. Miss Helen Stearns has transplanted a quantity of it to her garden.

EEL-GRASS FAMILY

Anacharis densa (Planch.) Vitt. (Waterweed)

A tropical plant native of South America which has previously been recorded only from Florida. Specimen: Lake Lanier, Oct. 21, 1936. *Fide*, N. C. Fassett. No. TR122. Lake Lanier is in Greenville Co., S. C.

GRASS FAMILY

Eulalia viminea (Trin.) Ktze.

Adventive from Africa, this grass seems to have made its entry through Norfolk, Virginia, whence it has spread southward. It is of such recent advent that it is not noted in Small's new Manual. Specimen: fields and roadsides, Oct. 7, 1936. No. TR34. *Fide*, Agnes Chase.

Eragrostis hirsuta (Michx.) Nees.

A roadside grass. Specimen: Sept. 28, 1936. No. TR20. *Fide*, Agnes Chase.

Eragrostis spectabilis (Pursh) Steud.

A beautiful grass. Specimen: In deep mountain woods, Oct. 4, 1936. No. TR98. *Fide*, Agnes Chase.

Sorghastrum Elliottii (Mohr.) Nash. (Indian Grass).

Specimen: Sunny mountain slopes, Oct. 10, 1936. No. TR61. *Fide*, Agnes Chase.

SEDGE FAMILY

Carex gynandra Schweinitz

Specimen: By a stream in a forest at the old Poinsett bridge, foot of Calahan Mt., May 13, 1937. No. TR186. This locality is in Greenville Co., S. C.

Carex hystericina Muhl.

Specimen: Beside the Saluda River at Merrittsville, May 13, 1937. No. TR187. This locality is in Greenville Co., S. C.

LILY FAMILY

Convallaria majalis L. (Lily-of-the-valley)

This beautiful little flower was shown me in bloom in Mr. William Weigel's garden. He brought his plants from the west slopes of Melrose Mt.

Trillium Underwoodii Small

This plant, intermediate in many ways between *T. simile* and *T. Hugeri*, has undoubtedly been here all along, but was passed over. On March 24, 1937, I took a satisfactory specimen of it, however, adding a new *Trillium* to the already impressive local array of this genus. Specimen: No. TR190.

Trillium grandiflorum (Michx.) Salisb.

In the *Flora of the Tryon Region* I reported only the variety *parvum* of this species. Miss May E. Day of Oberlin, Ohio, called my attention to the fact that the true species also flourishes here, and in 1937 I found plenty of it, and none of var. *parvum*. This makes one wonder if the peculiar little variety is not merely a depauperate phase thrown up by the plant in years somehow unfavorable.

Trillium declinatum (Gray) Gleason

I had never previously seen specimens of this species from North Carolina, and did not report it in my monograph of the genus in North and South Carolina. The range as described in Small's new Manual seems not to include the Carolinas. All that I found were in a single locality, at Bear Creek, Buck Mt. The flowers are deliciously fragrant, but not like those of any other *Trillium*. With its white ovary, rose-purple stigmas, and lilac anthers it is a striking flower. Specimen: April 26, 1937. No. TR168.

Trillium Vaseyi Harbison.

The only specimens were seen May 15, 1937, at Pearson's Falls. As this is now a wildflower preserve it was not possible to take away any plants. But of course there can be no doubt about the striking flower which looks much like *Trillium simile* but with curled sepals, maroon-rose petals, and declined or horizontal flower. The odor of roses was marked.

ORCHID FAMILY

Spiranthes cernua (L.) Richard. (Ladies' Tresses)

By shady mountain springs. Specimen: Oct. 14, 1936. No. TR140.

BIRCH FAMILY

Corylus cornuta Marsh. (Beaked Hazelnut)

Corylus rostrata Ait.

On high ridges, Rocky Spur. Specimen: Nov. 2, 1936. No. TR140. *Fide*, Edw. Palmer. Rocky Spur is in Greenville Co., S. C.

KNOTWEED FAMILY

Rumex obtusifolius L. (Dock)

Common weed of European origin. Specimen: Oct. 7, 1936, by a spring, Whiteoak Mt. No. TR88.

Polygonum hydropiperoides Michx. (Mild Water Pepper)
In a brook, Valhalla. Specimen: Sept. 28, 1936. No. TR18.

PINK FAMILY

Dianthus Armeria L. (Deptford Pink)
I have no specimen of this little European waif, owing to the fact that I noticed it only while waiting to board the train to leave the Tryon region, May 28, 1937. It was present in some abundance in grass, and is of course an unmistakable species. It will undoubtedly spread, as it is naturalized elsewhere in the neighboring counties and should bloom all summer.

WATER-LILY FAMILY

Nymphaea odorata Ait. (Fragrant Water-lily)
Common in the shallow west bays of Lake Lanier. Specimen: Oct. 21 (still in flower), 1936. TR115. *Fide*, N. C. Fassett.

BUTTERCUP FAMILY

Aconitum uncinatum L. (Clambering Monkshood)
Mr. William Wiegel, who gave me my specimen (No. TR188) from his garden, collected this on dry hills near Lynn. We searched for it, but could not find it in May. It blooms, of course, in autumn.

STRAWBERRY SHRUB FAMILY

Calycanthus fertilis Walt. (Strawberry Shrub)
In the *Flora of the Tryon Region* I reduced this species to a synonym of *C. floridus*, but I am convinced on further investigation that this is a valid species and I was in error. It is common around Tryon.

MUSTARD FAMILY

Draba verna L. (Whitlow Grass)
This very precocious little lawn weed, adventive from Europe, is now established in many places. Specimen: The Golf Links, March 10, 1937. No. TR151.

ROSE FAMILY

Pyrus angustifolia Ait. (Narrow-leaved Crabapple)
Specimen: slopes of Tryon Mt., April 19, 1937. No. TR168.

Crataegus communis Beadle. (Hawthorn)
Common little shrub, holding its fruits much later than any other species. Specimen: In fruit, Oct. 14, 1937. No. TR91. *Fide*, Edw. Palmer.

Rubus argutus Link. (Blackberry). Open banks, Lynn. Specimen: May 16, 1937. No. TR190.

Rubus nigrobaccus Bailey. (Blackberry). Open banks, Pacolet Gorge. Specimen: May 6, 1937. No. TR179.

Rubus betulifolius Small. (Blackberry). Open banks, by the old Poinsett bridge, foot of Calahan Mt. Specimen: May 13, 1937. No. TR185.

The three species of *Rubus* were identified according to Small's new Manual. The treatment in Gray's Manual did not describe any of these specimens at all.

PEA FAMILY

Trifolium dubium Sibth. (Least Hop Clover)
In lawns; native of Europe. Specimen: April 30, 1937. No. TR176.

WOOD-SORREL FAMILY

Oxalis corniculata L. (Sorrel)
Oxalis repens Thunb.
Little weed, probably of foreign origin, in garden plots.
Specimen: Oct. 27, 1936. No. TR102.

VINE FAMILY

Vitis Baileyana Munson
Trailing high in woods, "Valhalla". Specimen: In fruit, Oct. 2, 1936. No. TR35. *Fide*, Edw. Palmer.

ST. JOHN'S-WORT FAMILY

Ascyrum linifolium Spach. (St. Peter's-wort)
A low shrub, frequent in pine woods. According to Small's Manual this is a coastal plain plant. Specimen: Oct. 21, 1936. No. TR24. *Fide*, Edw. Palmer.

VIOLET FAMILY

Viola Lovelliana Brainerd.

Thinking the plants I found to be *V. triloba*, I took only a single specimen. On examination, however, it was found that the plant is pubescent only on the unfolding leaves and swiftly becomes glabrous. Every detail tallies with the description in Small's Manual and with the two drawings of *V. Lovelliana* in Brainerd's violet monograph (Vt. Agr. Expt. Sta. Bull. **224**: pp. 33–35). A search of every species in Brainerd's monograph on violet hybrids (Vt. Agr. Expt. Sta. Bull. **239**) fails to reveal anything that describes my plant, and it is to be remembered that Brainerd himself collected hybrids here assiduously in several years.

Viola Lovelliana is supposed to be confined to Louisiana, Arkansas and Oklahoma. That it has not been collected in intermediate states does not mean that it does not occur there, but only, perhaps, that collectors neglect violets as too difficult.

Specimen: Foot of Chimneytop Mt., April 28, 1937. No. TR169.

Viola Priceana Pollard (Confederate Violet)

In the *Flora of the Tryon Region*, following Brainerd, I considered this a mere albino, and a garden plant at that, of *V. papilionacea*. In the spring of 1937 however I discovered it in meadows where it was almost certainly wild. Further, Small has shown in his new Manual, p. 888, that the so-called Confederate Violet is a good species, while the albino form of *V. papilionacea* is an entirely different flower.

HEATH FAMILY

Gaultheria procumbens L. (Wintergreen)

Mrs. George Holmes showed me a small colony of this on the east slopes of Godshaw Hill. It has never been noted elsewhere in the county. Specimen: Leaves only, Nov. 27, 1936. No. TR143.

PRIMROSE FAMILY

Lysimachia Nummularia L.

Introduced from Europe; flowers in summer. This curious little plant is now naturalized well away from cultivation.

MILKWEED FAMILY

Vincetoxicum suberosum (L.) Britton (Angle-pod)

Gonolobus suberosus R. Brown

Cynanchum suberosum L.

Small in his Manual gives this only as a coastal plain plant. Twining on bushes. Specimen: "Valhalla", in fruit, Nov. 16, 1936. No. TR142.

MORNING GLORY FAMILY

Cuscuta indecora Choisy. (Dodder)

Cuscuta decora Engelm.

Collected July 20, 1933, near the Boy Scout Camp on Lake Lanier, but within the North Carolina boundary, by Budd Elmon Smith, who reports it in Elisha Mitchell Society Journal **50**: 289–90, as new to the state. Smith reports it growing on legumes and asters.

Cuscuta compacta Jussieu. (Dodder)

Collected by Budd Elmon Smith (loc. cit.) from Polk Co. Specimen not seen.

PHLOX FAMILY

Phlox nivalis Loddiges. (Snowy Phlox)

This plant was collected by Miss Kimber in April, 1930, in the eastern part of the county. Specimen not seen by me, but identified by Dr. Wherry.

Phlox carolina L. (Carolina Phlox)

Considered by Dr. Edgar T. Wherry, our best authority, as distinct from *Phlox ovata* (which is also present), this is quite a common plant and remains remarkably long in flower. Specimen: Rocky Spur, Nov. 2, 1936. No. TR136.

POTATO FAMILY

Datura Stramonium L. (Stramonium, Jimson-weed)

A field weed, adventive from the American tropics. In fruit, March 18, 1935.

Physalis pubescens L. (Ground Cherry)

On dry sunny mountain fields. Specimen: Oct. 13 (in fruit), 1936. No. TR92.

MINT FAMILY

Pycnanthemum muticum Michx. (Mountain Mint)

Koellia mutica Britton.

Common in fields and along waysides. Specimen: Oct. 3, 1936. No. TR17.

COMPOSITES (ALL EXCEPT THE VERNAL IDENTIFIED BY S. F. BLAKE)

Vernonia noveboracensis (L.) Willd. (Purple Ironweed)
In woods and fields. Specimen: Oct. 4, 1936. No. TR16.

Eupatorium incarnatum Walt.
A beautiful pink or pale purple flower. Frequent in cool glens. Specimen: Sept. 28, 1936. No. TR23.

Senecio aureus L. (Golden groundsel)
Common, open banks; the earliest of the senecios to bloom. Specimen: Fishtop, in fields, April 28, 1937. No. TR174.

Solidago Curtisii T. & G. (Golden-rod)
Common on sunny mountain slopes. The var. *pubescens* had already been collected here. Specimens: Oct. 14, 1936. Nos. TR68 and TR85.

Solidago petiolaris Ait. (Golden-rod)
On Melrose Mt. in deep woods. The var. *angustata* had already been collected here. Specimen: Oct. 14, 1936. No. TR80.

Solidago altissima L. (Golden-rod)
Roadsides, common. Specimen: Oct. 7, 1936. No. TR56.

Aster concolor L.
A beautiful and dainty little silver-leaved species found on sunny mountain slopes. Specimen: Oct. 14, 1936. No. TR76. This confirms my report in the *Flora of the Tryon Region* of its probable occurrence. In the *Flora* I also listed *Aster linariifolius* as having been reported, without specimens, by Miss Wright many years ago. This species also was confirmed by a specimen of that attractive little species which I took Oct. 14, 1936.

Aster Curtisii T. & G.
Roadsides, very common. Specimens: Oct. 7, Oct. 9, Oct. 17, 1936. Nos. TR40, TR51, TR65, TR88, TR91.

Aster pilosus Willd. var. *platyphyllus* (T. & G.) Blake.
Roadsides, common. Specimens: Sept. 28 and Oct. 7, 1936. Nos. TR24 and TR53.

Aster laevis L.

Frequent, along roadsides and in fields. Specimens: Oct. 7, 1936. No. TR43.

Baccharis halimifolia (Groundsel Tree)

This sea beach and salt marsh plant is certainly a surprising stray to find here. A large bush hangs over a roadside south of Clarke's Mt., in Greenville Co., S. C., in the extreme northeast square mile of the county. April 28, 1937. No. TR175.

Xanthium americanum Walt. (Cocklebur)

Xanthium pungens Wallr.
Xanthium pennsylvanicum Wallr.
Xanthium glabratum Britton
Xanthium canadense Mill.
A common field weed. Specimen: In fruit, Nov. 3, 1936.

Helenium tenuifolium Nutt. (Spanish Daisy)

A common and gay roadside weed. Specimen: Oct. 18, 1936. No. TR104.

Erechtites hieracifolia (L.) Raf. (Fireweed)

Roadsides and clearings, common. Specimens: Oct. 7 and Oct. 20, 1936. Nos. TR55 and TR120.

Cosmos bipinnatus Cav.

Native of tropical America, this well known garden flower is now so abundantly naturalized along roadsides that it must be admitted to the flora.

Hieracium scabrum Michx. (Hawkweed)

By roadsides and in fields. Specimens: Oct. 7, 1936. No. TR47.

Prenanthes serpentaria Pursh (Snakeroot)

In mountain woods. Specimen: Oct. 14, 1936. No. TR67.

Tragopogon pratensis L. (Goatsbeard)

Now a common wayside weed.

DELETIONS

The following species, reported in the *Flora of the Tryon Region* are there in error and must be excluded from the local flora:

Selaginella tortipila

The only voucher for this species in the local flora was one collected by Dr. Wherry, who has changed his identification of it to *S. rupestris.*

Tiarella macrophylla

According to Dr. Wherry this species is a chimera, the flowers on the type specimen, collected from the Tryon region, being those of typical *Tiarella cordifolia* while the leaves are those of *Heuchera villosa.*

Viola Stoneana

The specimens on which this report was based were misidentified by me and turn out to be several other sorts of violets.

Phlox divaricata

Reported in error.

Aster junceus

Specimens wrongly identified.

Antennaria occidentalis

Specimens wrongly identified.

CORRECTIONS

Introduction, p. 108, line 3; for "are", read: is
Introduction, p. 108, line 28; for "profit by" read: reward.
Species 4, line 1; for "Braken", read: Bracken.
Species 7, line 2; for "rare", read: frequent.
Species 62, line 2; after "and" add: waste.
Species 75, line 1; for "*Nothoholcus,*" read: *Notholcus.*
Species 89, line 1; for "*berteroanus,*" read: *Berteroanus.*
Species 106, line 3; for "species", read: species.
Species 131, line 1, for "*halepense*", read: *halepensis.*
Species 203, delete lines 6 and 7.
Species 233, line 6; after 1927, add: (Wherry).
Species 255, line 2; for "aculis", read: acaulis.
Species 259, line 3; for "*Caiëtes*", read: *Cleiestes.*
Species 280, line 3; after Valhalla, add: (in fruit).
Species 285, line 1; for "K. Koch", read: C. Koch.
Species 307; this should be deleted, and the following substituted:
Celtis occidentalis L. (Hackberry)

Large tree, occasional in the mountain valleys. Our specimens differ in having garnet-red drupes and falcate leaves.
Species 316, line 10; for "kidnev," read: kidney.
Species 321, line 3; for "Britton", read: J. Britten.
Species 392, line 1; after *acuminata*, add: L.
Species 478, line 4; for "species", read: specimen.
Species 524, line 2; for "*Podalyriax*" read: *Podalyria.*
Species 637, line 1, after *Buckleyi*, insert: M. A. Curtis.
Species 678, line 5; for "May 5, 1911 (Tryon" read: Tryon, May 5, 1911 (Day).
Species 698, line 3; after *acutaefolium*, add: of Auths., not Michx.
Species 719, line 3; for "smal er", read: smaller.
Species 755, line 7; after 1897, add: (Towns.)
Species 753, line 4; after 1897, add: (Towns.)
Species 825, line 1, for "*clinopodia*", read: *Clinopodia.*
Species 831, line 4; for "*Ociganum*" read: *Origanum.*
Species 852, line 1; for "*Pentstemon*" read: *Penstemon.*
Species 862, line 4; for "Scherb." read: Schub.
Species 866, line 1; for "*austromantana*", read: *austromontana.*
Species 872, line 7; for "Valley", read: gorge.
Species 940, line 1; for "L." read: (L.) DC.
Species 959, line 3; for "in some places", read: as in some places.
Species 1008, line 2; for "*infirma*" read: *infirmus.*
Species 1010, line 2; for "*linifolius*", read: *linifolia.*
Species 1058, line 1; for "*Chicorium*", read: *Cichorium.*
Species 1059, line 2; for "*Taraxicum*", read: *Taraxacum.*
Species 1073; in the note appended, for "Tyron", read: Tryon.
Errata, species 614, for "line four," read: line 3.
Errata; delete completely the reference to species 720.
Errata, seventh line from the bottom of p. 156; for 848, read: 849.
List of New Names and Combinations (following Species 1073) species 380, for "Forma *Hugeri* Weatherby, read: Forma *laevicaulis* Harger. Rhod. **31**: 164. 1929.

THE MOSSES OF FRANKLIN COUNTY, NORTH CAROLINA

By Lewis E. Anderson and Evelyn S. Beaven

An intensive study of the mosses of any small area is valuable. It not only adds to our knowledge of plant distribution but is helpful in establishing local habitat relationships and provides data that are often useful in making broader ecological generalizations. Franklin County was selected for the present study because it is situated on the borderline between the piedmont and coastal plain regions and thus offers excellent opportunities for studying the floristic transition between the two regions. This was the ultimate aim of the study.

Franklin County is located in the north-central part of North Carolina on the eastern edge of the Piedmont Plateau. The extreme eastern part lies within the coastal plain, while the western two-thirds is in the piedmont. In many places along the border of the two regions the sandy surface soil has been removed by erosion, thus exposing extensive areas of rock. These rock outcrops are characteristic of the transition region not only in Franklin County but in adjacent counties to the north and south as well. There are two main groups of soils in the county, the gray sandy surface soils, derived from upper coastal plain material and the red clay loam soils of the piedmont which are derived from crystalline rock. There is no sharp line of demarcation between these two types of soils. Isolated areas of gray sandy soil may appear in a section dominated by red clay while conversely small clay areas may be scattered within a more extensive sandy region.

Leo Lesquereux pointed out many years ago that mosses have their geological and lithological preferences far better marked than any other kind of plant. While there are many mosses which grow indifferently on a variety of substrata, there are some which are quite restricted as to habitat. It is thus possible to group the latter accordingly. In the present study nearly 600 collections of mosses were made within the county. As complete notes as possible were made regarding the habitat of each collection so that the full range of substrata for each species could be determined. The classification below follows that of Warming, which is based upon water requirements, i.e. into xerophytes, mesophytes, and hydrophytes. Further subdivision is necessary, however, in the case of mosses, to include the type of substratum.

XEROPHYTES: Plants which grow on substrata containing mostly very small amounts of water.

1. Plants growing on more or less exposed rocks.

Grimmia laevigata
Grimmia pilifera
Hedwigia ciliata
Ptychomitrium incurvum

2. Plants growing on the bark of living trees.

Clasmatodon parvulus
Drummondia prorepens
Orthotrichum ohioense
Thelia hirtella
Cryphaea glomerata
Leptodon trichomitrion
Orthotrichum stellatum

3. Plants growing on soil, mostly old fields, roadsides, or open woods.

Pogonatum brachyphyllum
Bruchia Sullivanti
Dicranum condensatum
Ditrichum pusillum
Thelia Lescurii
Ditrichum pallidum
Polytrichum juniperinum

MESOPHYTES: Plants adapted to soil containing a moderate amount of water—essentially plants of shaded habitats.

1. Plants growing on moist shaded soil at the edge or banks of streams.

Bryhnia Novae-angliae
Eurhynchium hians
Atrichum undulatum
Mnium affine

HYDROPHYTES: Plants which are completely or partly submerged or which grow in very wet places.

1. Plants submerged or floating in water.

Aulacomnium heterostichum
Dicranum fuscescens
Tortella caespitosa
Plagiothecium micans
Leucobryum albidum
Polytrichum ohioense
Cirriphyllum Boscii
Campylium hispidulum
Eurhynchium serrulatum
Hypnum imponens
Hypnum curvifolium

2. Plants attached to rocks in water or wet by dripping or spraying water.

Fontinalis flaccida
Leptodictyum riparium var. *fluitans*
Fissidens Julianus

3. Plants growing in shaded woods, on soil at the base of trees, on humus or decaying wood.

Fissidens incurvus
Bryum bimum
Hygroamblystegium orthocladon
Hygroamblystegium irriguum

4. Plants growing in open bogs.

Aulacomnium palustre
Philonotis fontana
Hypnum arcuatum
Sphagnum imbricatum
Sphagnum subsecundum
Sphagnum imbricatum var. *affine*

5. Plants growing in more or less wooded swamps.

Climacium Kindbergii
Sphagnum (most species)
Brachythecium plumosum
Climacium americanum
Thuidium microphyllum
Campylium chrysophyllum

Studies along the border of the coastal plain and piedmont failed to show any sharp distinction between the plants of the two regions. The only piedmont plants which cease abruptly at the line are those few species which grow exclusively on rocks, i.e. *Grimmia* spp., *Hedwigia ciliata*, and *Ptychomitrium incurvum*. That they do not occur in the coastal plain of Franklin County is due merely to the absence of rocks. In other counties of the coastal plain in which there are rocks these species are found in abundance. In the case of soil- and tree-growing species there is a general overlapping in the two regions. For instance, *Dicranum condensatum*, a typical plant of the sand hills of the coastal plain, was found growing throughout the county wherever there was any semblance of sandy soil of a xerophytic nature, irrespective of the two regions. Toward the western part of the county, however, it becomes less frequent and even rare due to the absence of suitable habitats. Other plants of the coastal plain exhibit this same type of distribution with a greater or lesser degree of overlapping. The species placed in this category are:

Sphagnum imbricatum
Pogonatum brachyphyllum
Funaria serrata
Atrichum crispum
Dicranum condensatum
Fontinalis flaccida

It should be noted that all of the above are plants which grow on soil, with the exception of *Fontinalis*. The epiphytes, as might be expected, are equally abundant in the two regions and none of the lower coastal plain species were found in Franklin County with the exception of *Entodon Drummondii* which was depauperate. Such plants as *Syrrhopodon*

texanus, *Schlotheimia Sullivantii*, *Hypnum arcuatum* var. *americanum*, *Plagiothecium micans* var. *fulvum*, and *Dichelyma capillaceum* which are exceedingly abundant locally in the large swamps near the coast do not extend into Franklin County.

Of especial interest are the exposed rock outcrops referred to above which were studied in detail. Since the vegetation is essentially the same on all of these outcrops a description of one, known locally as "Flat Rock," will suffice. This outcrop is an extensive somewhat evenly eroded granitic exposure which slopes gradually from either side to the center through which a small stream flows. On each side of the stream the rock is dry and exposed to the sun during a large part of the day, thus offering an exceedingly xerophytic habitat. Areas of this nature support almost exclusively mats of *Hedwigia ciliata*, *Grimmia laevigata*, and *G. pilifera*, which, after a period of time retain a certain amount of soil. Where soil accumulation is sufficient the flowering plant, *Talinum teretifolium* Pursh, grows along with *Selaginella rupestris* (L.) Spreng. and several species of lichens. Soil is apparently built up in these otherwise bare areas in such a manner. Other species of flowering plants which eventually inhabit these mats are *Lonicera japonica* Thunb., *Bignonia capreolata* L., *Panicum* spp., *Solidago* sp., *Rhus copallina* L., and *Opuntia vulgaris* Mill. In the more moist situations along the stream *Anomodon attenuatus*, *Hypnum arcuatum*, and *Climacium americanum* flourish, often with mixtures of *Philonotis fontana* and *Atrichum undulatum*.

The check list of species collected in the county follows the arrangement of Grout in his Moss Flora of North America.

Order SPHAGNALES

Family SPHAGNACEAE

Sphagnum imbricatum Hornsch. On soil in boggy situations. Not common.

Sphagnum imbricatum var. affine (Ren. & Card.) Warnst. Bogs. Rare.

Sphagnum subsecundum Nees. Bogs. Common.

Order BRYALES

Family POLYTRICHACEAE

Atrichum angustatum (Brid.) Bryol. Eur. On soil in various situations, roadsides, old fields, open woods, etc. Common.

Atrichum crispum (James) Sull. Moist sandy soil, bank of streams. Rare.

Atrichum undulatum (Hedw.) Beauv. Moist soil, edge of streams, woods, fields, etc. Common.
Pogonatum brachyphyllum (Rich.) Beauv. Clayey banks. Not common.
Pogonatum pensilvanicum (Hedw.) Paris. Somewhat moist clay banks. Not common.
Polytrichum commune Hedw. Moist soil, swamps. Common.
Polytrichum juniperinum Hedw. In dry situations, often on rocks with a thin covering of soil. Uncommon.
Polytrichum ohioense Ren. & Card. Dry soil, woods, banks, roadsides, etc. Common.

Family FISSIDENTACEAE

Fissidens Bushii (Card. & Thér.) Card. & Thér. Clayey soils, banks, slopes, etc., in woods. Rare.
Fissidens Julianus (Mont.) Schimp. On rocks in running water. Not uncommon.
Fissidens taxifolius Hedw. Clayey soils, woods. Not common.
Fissidens viridulus (Web. & Mohr) Wahlenb. On rocks in streams. Common.
Fissidens viridulus var. tamarindifolius (Brid.) Grout. On stones in streams. Rare.

Family ARCHIDIACEAE

Archidium ohioense Schimp. Soil in old fields. Rare.

Family DITRICHACEAE

Pleuridium subulatum (Hedw.) Lindb. Soil in old fields. Common.
Bruchia Sullivanti Aust. Old fields. Common.
Ceratodon purpureus (Hedw.) Brid. Dry soil on rocks, roadsides, and fields. Common.
Ditrichum pallidum (Hedw.) Hampe. On soil in various situations. Exceedingly common.
Ditrichum pusillum (Hedw.) E. G. Britton. Old fields and roadsides. Common.

Family DICRANACEAE

Dicranella heteromalla (Hedw.) Schimp. Soil, old fields, bank of streams, and roadsides. Common.
Dicranum condensatum Hedw. Dry sandy soil in open woods. Common.
Dicranum spurium Hedw. Shaded dry sandy soil. Common.

Dicranum scoparium Hedw. On soil, usually humus, in woods. Exceedingly common.
Dicranum fuscescens Turn. Decayed wood, woods. Common.
Dicranum flagellare Hedw. Decayed wood, shaded places. Not common.
Dicranum rugosum (Hoffm.) Brid. Humus in woods. Rare.

Family LEUCOBRYACEAE
Leucobryum albidum (Brid.) Lindb. Soil, decayed wood, and bases of trees. Common.
Leucobryum glaucum (Hedw.) Schimp. Soil in shaded places. Common.

Family POTTIACEAE
Weisia viridula Hedw. Dry soil. Exceedingly common.
Tortella caespitosa (Schwaegr.) Limpr. Soil and decaying wood, base of trees. Common.
Barbula unguiculata Hedw. On brick walls. Rare.
Acaulon triquetrum (Spruce) Muell. Soil in old field. Rare.
Tortula muralis Hedw. Brick walls. Rare.

Family GRIMMIACEAE
Grimmia laevigata (Brid.) Brid. Exposed rocks. Common.
Grimmia pilifera Beauv. Exposed rocks. Rather uncommon.
Hedwigia ciliata Hedw. Bare rocks. Common.
Ptychomitrium incurvum (Muhlenb.) Sull. Rock crevices. Common.

Family FUNARIACEAE
Physcomitrium turbinatum (Michx.) Brid. Moist soil, fields and pastures. Common.
Funaria flavicans Michx. Waste places and bare soil, especially burned-over areas, often mixed with the next. Not common.
Funaria hygrometrica Hedw. Same substrata as the last. Common.
Funaria serrata Brid. Moist sandy soils, banks and fields. Not common.

Family ORTHOTRICHACEAE
Orthotrichum ohioense Sull. & Lesq. Bark of trees. Common.
Orthotrichum stellatum Brid. Bark of trees. Not as common as the last.
Drummondia prorepens (Hedw.) Jennings. Bark of trees. Common.

Family BARTRAMIACEAE

Bartramia pomiformis Hedw. Soil in shaded places, occasionally on rocks. Common.

Philonotis fontana Brid. Soil and rocks in boggy places. Common.

Philonotis Muhlenbergii (Schwaegr.) Brid. Bogs and moist rocks. Rare.

Family AULACOMNIACEAE

Aulacomnium heterostichum (Hedw.) Bryol. Eur. On soil in woods, often at bases of trees. Common.

Aulacomnium palustre Schwaegr. Bogs and on rocks. Common.

Family BRYACEAE

Pohlia nutans (Hedw.) Lindb. On various substrata. Common.

Pohlia Wahlenbergii (Web. & Mohr) Andrews. Moist shaded soil. Not common.

Leptobryum pyriforme (Wils.) Schimp. Moist rocks. Rare.

Bryum argenteum Hedw. Soil, roadsides and waste places. Common.

Bryum bimum Brid. Wet rocks. Common.

Bryum caespiticium Hedw. Soil, various places. Not common.

Bryum capillare Hedw. Moist situations, often bases of trees. Not common.

Rhodobryum roseum Schimp. Base of trees and stumps. Not common.

Family MNIACEAE

Mnium affine Schwaegr. Shaded soil in moist places. Common.

Mnium affine var. ciliare (Grev.) C. Muell. Moist soil, especially along streams. Common.

Mnium cuspidatum Hedw. Moist soil in woods. Common.

Mnium medium Bryol. Eur. Humus. Rare.

Mnium rostratum Schwaegr. Soil, shaded situations. Rare.

Family HYPNACEAE

Subfamily Climacieae

Climacium americanum Brid. Moist shaded situations. Rather common.

Climacium Kindbergii (Ren. & Card.) Grout. Growing in or at the edge of water. Common.

Subfamily Beachythecieae

Bryhnia Novae-Angliae (Sull. & Lesq.) Grout. Sandy soil, edge of streams. Rare.

Eurhynchium hians (Hedw.) J. & S. Moist shaded soil. Common.
Eurhynchium pulchellum (Hedw.) Jennings. Moist sandy soil. Common.
Eurhynchium serrulatum (Hedw.) Kindb. Soil and humus in various situations. Exceedingly common.
Cirriphyllum Boscii (Schwaegr.) Grout. Shaded soil. Common.
Chamberlainia acuminata (Hedw.) Grout. Base of trees. Rare.
Brachythecium oxycladon (Brid.) J. & S. Soil, open woods and occasionally fields. Common.
Brachythecium plumosum Bryol. Eur. Soil, edge of streams. Not common.
Brachythecium salebrosum (Hoffm.) Bryol. Eur. Soil, banks, slopes, etc., in woods. Not common.

Subfamily Amblystegieae

Leptodictyum riparium (Hedw.) Warnst. Partially inundated rocks. Not uncommon.
Leptodictyum riparium var. fluitans Lesq. & James. In running water. Rare.
Leptodictyum riparium var. longifolium Schultz. Stagnant water. Rare.
Amblystegium varium (Hedw.) Lindb. Various substrata. Common.
Hygroamblystegium irriguum (Wils.) Loeske. In wet soil and in water. Common.
Hygroamblystegium orthocladon (Beauv.) Grout. In streams. Common.
Campylium chrysophyllum (Brid.) Bryhn. On soil and rocks with a thin layer of soil. Common.
Campylium chrysophyllum var. brevifolium (Ren. & Card.) Grout. On soil, edge of streams. Common.
Campylium hispidulum (Brid.) Mitt. Decaying wood, stumps, etc. Not uncommon.
Drepanocladus aduncus (Hedw.) Warnst. var. Kneiffii (Bryol. Eur.) Warnst. In bogs and swampy situations. Not common.

Subfamily Hypneae

Hypnum arcuatum Lindb. In boggy situations. Common.
Hypnum curvifolium Hedw. Decaying wood and soil in shaded places. Not common.
Hypnum imponens Hedw. Soil and decaying wood. Uncommon.
Hypnum molluscum Hedw. Soil, bases of trees. Rare.

Heterophyllum Haldanianum (Grev.) Kindb. Moist decaying wood. Rare.
Sematophyllum adnatum (Michx.) E. G. Britton. On bark of living trees. Common.
Sematophyllum carolinianum (C. Muell.) E. G. Britton. Moist rocks. Rare.
Homomallium adnatum (Hedw.) Broth. Bark of trees, decaying wood, and rocks. Not common.
Pylaisia intricata (Hedw.) Bryol. Eur. Bark of living trees. Not common.
Pylaisia Selwynii Kindb. On trees. Uncommon.
Platygyrium repens (Brid.) Bryol. Eur. Decayed wood. Common.

Subfamily Plagiothecieae

Plagiothecium denticulatum (Hedw.) Bryol. Eur. On soil and humus in shaded places. Not common.
Plagiothecium micans (Sw.) Paris. Decaying wood. Common.

Subfamily Entodonteae

Entodon cladorrhizans (Hedw.) C. Muell. Moist rocks. Rare.
Entodon Drummondii (Bryol. Eur.) J. & S. Bark of tree. Rare.
Entodon seductrix (Hedw.) C. Muell. Soil and rocks. Common.

Family LESKEACEAE

Thuidium delicatulum (Hedw.) Mitt. Various substrata. Common.
Thuidium microphyllum (Hedw.) Best. Soil and decaying wood in woods and swampy situations. Common.
Thuidium virginianum (Brid.) Lindb. Soil in rather dry situations. Not common.
Leskea gracilescens Hedw. Bark of trees and decaying logs with soil. Not common.
Leskea obscura Hedw. Bark of trees. Common.
Thelia asprella Sull. Base of trees. Common.
Thelia hirtella (Hedw.) Sull. Tree trunks. Rare.
Thelia Lescurii Sull. Sandy soil and rocks with a thin layer of soil. Not uncommon.
Anomodon attenuatus (Hedw.) Hueben. Soil in bottom land and at bases of trees and rocks. Common.
Anomodon rostratus (Hedw.) Schimp. Bases of trees and rocks. Common.

Family LEUCODONTACEAE
Leucodon julaceus (Hedw.) Sull. Bark of trees. Common.
Leptodon trichomitrion (Hedw.) Mohr. Bark of trees. Not common.

Family CRYPHAEACEAE
Cryphaea glomerata Schimp. Bark of trees. Common.
Cryphaea nervosa (Hook. & Wils.) Bryol. Eur. Bark of trees, often mixed with the last. Rare.

Family FABRONIACEAE
Clasmatodon parvulus (Hampe) Sull. Bark of trees and decaying wood. Common.
Schwetschkeopsis denticulata (Sull.) Broth. Bark, bases of trees. Rare.

Family FONTINALACEAE
Fontinalis flaccida Ren. & Card. In water. Not common.

The writers are indebted to Professors H. L. Blomquist and H. J. Oosting for helpful suggestions and criticisms during the course of the work.

DEPARTMENT OF BOTANY,
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DURHAM, NORTH CAROLINA.

THE MORPHOLOGY OF THE PERITHECIUM OF SORDARIA FIMICOLA (ROB.) CES. AND DE NOT.

By Don Ritchie

Plates 28 and 29

The first important work on the Sordariaceae was done by Dangeard (8) in 1907. He decided for *Sordaria fimicola* that there was no antheridium and no fertilization, that the cells of the ascogonium were multinucleate, and that the asci were produced from the ascogonium by crozier formation. He made no further observations on the nuclear behaviour of the fungus. *Sordaria macrospora* was described as essentially similar except that it has a straight, intercalary archicarp instead of a coiled, terminal one. Only in *Sporormia intermedia* he did describe binucleate cells in the ascogonium and even went so far as to say "One would be tempted . . . to think of a fusion."

Satina (17) has also contributed important developmental studies on the Sordariaceae. In the several members of this family considered, she describes the same multinucleate, coiled ascogonium, without an antheridium, and the ascogenous hyphae coming from the ascogonium. Paired nuclei were seen, but not in the cells which formed asci. Large nuclei and small nuclei were observed, but fusion was denied, the large nuclei being explained as "fully grown, ready for dividing."

MATERIALS AND METHODS

The material was collected on horse and cow dung and was got into pure culture by cracking the perithecia and placing the living masses of asci on agar plates. When the hyphae outgrew the bacteria, the clean ends were cut off and transferred to other plates. For this purpose various agars were used. Blakeslee's #230 proved to be the most satisfactory for the production of perithecia, as it becomes black with fruit about a week after inoculation. Prune decoction agar gives a heavy vegetative growth but fruiting is poor. On maltose-peptone, potato-dextrose, and corn-meal-yeast agar, *Sordaria fimicola* grows well, but not as luxuriously as on #230. Dung agars made from decoctions of cow, horse, or sheep dung, did not give any better growth than that

which was obtained on plain, non-nutrient agar. Cultures were also made by letting the perithecia shoot spores onto agar plates. Germination was attempted on all the agars on which the fungus was grown, but the spores did not germinate on any except plain, non-nutrient agar. Some of the spores were placed for several hours in the sunlight, but without an increase either in the rapidity or percentage of germination. Various temperatures were used, as suggested by Dodge (9), but without success. However, on plain, non-nutrient agar, the spores will germinate readily either in the light or darkness at room temperatures (15–25 degrees C.).

Perithecial development was studied in living material until the perithecia became too opaque to observe. There is a period, as noted by Gilkinet (13), during which living material is worthless for study, as the thickening wall of the perithecium cannot be opened without destroying the contents. During this period (and this is just when the most interesting developments are taking place) sections must be used. For this purpose, the fungus was killed in various fixers. Carnoy's fluid caused plasmolysis. Chromic formalin and hot corrosive sublimate in 95% alcohol gave indifferent results. The Chicago formula (6) used instead of Flemming's weaker solution because of the lesser percentage of osmic acid, proved most satisfactory. Because of the air entrapped in the interstices of the aerial hyphae, the material to be fixed had to be kept under the aspirator for six to twelve hours. Zirkle's (18) N-butyl series of alcohols was used for dehydration and infiltration. Sections were cut at 5μ, and stained with Gram's gentian violet and iodine and with Heidenhain's iron alum haematoxylin, counterstained in Orange G, light green or fast green. The haematoxylin alone gave the clearest nuclear figures, while this stain followed by Orange G was most useful in bringing out the arrangement of the cells in the base of the perithecium.

THE MYCELIUM

The spores of *Sordaria fimicola* germinate by means of an apical germ pore, as shown by Gilkinet (13). A vesicle is given out, round and full of cytoplasm, from which proceed one to several hyphae (Fig. 1). These hyphae become septate, with perforations in the septa. The mature mycelium is composed of hyphae of various diameters, ranging from 3μ to 12μ in diameter. On media rich in nourishment, many aerial hyphae are produced, but on less nutrient, the mycelium keeps to the surface or burrows into the substratum.

Perithecia with eight-spored asci are formed in single-spore cultures, and thus the fungus is homothallic.

THE ARCHICARPS

At the time of the formation of the perithecial fundaments, as shown by previous workers on the Sordarias (Gilkinet, 13; Dangeard, 8; Satina, 17) certain of the ends of otherwise undifferentiated hyphae become coiled (Figs. 2 and 3). Septations appear (Fig. 4), but not with any apparent regularity such as Andrus (2) found for *Ceratostomella*. This coil, or archicarp, twists about itself for several turns. One or more hyphae may contribute to the formation of the archicarp (Figs. 2 and 3), which soon becomes invested with smaller, numerous vegetative hyphae (Fig. 5). Neither Dangeard (8) nor Satina (17) considered any of these as antheridia, and there is indeed no indication that any of them function in a sexual way. Usually there is no structure that can be interpreted as a trichogyne, though there appear occasionally unaccountable out-growths from the archicarp (Fig. 4). Neither are there any conidia such as Satina (17) shows for *Podospora curvula*, nor any spermatia such as Ames (1) describes for *Pleurage anserina*.

PERITHECIAL DEVELOPMENT

After the investment of the archicarp by the vegetative hyphae, the entire mass grows quickly, soon becoming too opaque to study. At this time the covering hyphae are so strong, and the contents so delicate, that crushing the perithecia destroys the inner cells. In sectioned material, however, it can be seen that the archicarp has grown into a homogeneous tangle of filaments which are already becoming pseudoparenchymatous in nature (Fig. 6). Even in the early stages, the outer layer of cells is heavier-walled than the internal portion. When the perithecial covering is still only one layer thick, there becomes differentiated in the center of the previously homogeneous tissue, a more deeply staining hypha (Fig. 7) which seems to be what Fuisting (12) described for *Stictosphaeria*, *Diatrype*, etc., as the Woronin hypha. Fisch (11), who considered Fuisting's paper "downright foggy," said, "It can not be doubted that the Woronin hypha arises as a new formation in the matrix, though its rise cannot be followed." He states that the Woronin hypha stains heavily, has very delicate walls, and grows to several times its original size. For *Xylaria*, however, Fisch (l.c., p. 879) rejects Brefeld's assertion that the asci arise from the Woronin hypha.

Similar organisms (in which the archicarp merely produces vegetative

growth) have been noted by several investigators. Nichols in 1896 (16) on *Hypocopra* found this to be true. Blackman and Wolsford (3) in 1912 found sexually non-functional archicarps in *Polystigma rubrum*, Jones in 1926 (15) noted a like situation in *Ophiobolus graminis*, as did Cookson in 1928 (17) on *Melanospora zamiae*.

As development proceeds, the thin-walled cells forming the center of the perithecium begin to disintegrate, and the cells of the outer layers become stouter, the outermost being darkly pigmented. In living material at this stage, many elliptical or roundish, thin-walled, apparently empty chains of cells can be seen, as Gilkinet (13) shows. These are probably nourishing cells, and are so delicate that they never keep their shape in fixed material. In sectioned perithecia these nourishing cells seem to be disintegrating progressively from the center to the outside (Figs. 10 and 12).

Now the deeply staining hypha (or hyphae) in the center of the perithecium appears to be broken up into numerous cells. Though never more than one hypha was seen at one time in a perithecium, it would be hard to say whether one or more hyphae are involved in this procedure because the resulting cells are so irregularly disposed (Figs. 9 and 13). The cells round off and separate from one another in a fashion similar to that found in *Xylaria* by Brown (4) and in *Ceratostomella* by Andrus (2). These irregularly arranged, deeply staining cells make up the ascogenous hyphae. Some of the cells are uninucleate, many are binucleate, and a few have three nuclei. These nuclei, like those Jones (15) found in *Ophiobolus*, show no internal detail.

DEVELOPMENT OF THE ASCOGENOUS HYPHAE

In *Sordaria fimicola* the paired nuclei fuse in the primary ascus cell (Figs. 13 and 14). The nuclei before fusion are considerably smaller than the fusion nucleus. Following fusion in the primary ascus cell, the ascus grows upward without forming the typical crozier, though occasionally regular ones are found (Figs. 11 and 15). This situation in *Sordaria fimicola* is substantiated by Faull (10) and is paralleled in *Ophiobolus graminis* as described by Jones (15), who says that typical croziers are sometimes formed and sometimes not. The same is true for *Cordyceps agariciformia*, according to Jenkins (14). Cookson (7) on *Melanospora zamiae*, Brown (4) on *Xylaria*, and Cayley (5) on *Nectria galligena* all describe the formation of asci from ascogenous cells without croziers.

Thus *Sordaria fimicola* is added to a growing list of species which

form asci from purely vegetative hyphae, a list which began with the study of *Xylaria* by Fisch (11) in 1882, and which now includes members of the Pseudosphaeriaceae, Hypocreales, Sordariaceae, Ceratostomaceae Gnomoniaceae, Xylariaceae, and Pezizaceae.

STRUCTURE OF THE PERITHECIUM

After the fusion of the nuclei in the ascogenous cells, the asci increase greatly in size and remain uninucleate until they have reached their full growth. Meanwhile, the layers of the perithecial wall have differentiated somewhat. The outermost layer, one cell thick, is heavily pigmented but fairly thin-walled. The layer next to the outside is several cells thick, and consists of extremely thick-walled cells. Inside that, a few layers of thin-walled cells form the lining of the perithecium. At the top of the perithecium, opposite the origin of the asci, the perithecial wall elongates, and the cells of the inner wall grow usually upward and outward, forming the periphyses, and making an opening, the ostiole, through what has by now become the neck.

CYTOLOGY OF THE ASCUS

The young ascus is distinguished by a mass of darkly staining material in the tip, and by the large fusion nucleus (Fig. 18). The dark material is seen in even the smallest asci in which fusion has taken place, and remains until the formation of the ring in the tip of the mature ascus. The fusion nucleus is relatively large, having a diameter half as great as the diameter of the ascus. It has a conspicuous nucleolus surrounded by a clear area. Outside the membrane are aggregated some dark masses of material, not distinct, but somewhat granular in nature, which are seen only at this time. Faull (10) also observed this. The cytoplasm of the ascus is denser at this time than at any later time, but is characteristically vacuolate at the lower end.

The first division in the ascus occurs with the spindle more or less parallel to the long axis of the ascus (Fig. 19). The chromosomes are too small and indistinct to be counted. The nucleolus remains at least through the metaphase as a large, distinct, dark body alongside the chromosomes.

Since there are comparatively few asci found between the time of the first mitosis and the delimitation of the spores, the remaining stages in ascus formation must pass rapidly. The nuclei resulting from the first division are smaller than the fusion nucleus, but still contain a prominent nucleolus, located in the nucleus in such a way that each nucleus

seems to have a beak pointing away from the other nucleus (Fig. 21). The second division follows with its spindle also practically parallel to the long axis of the ascus (Fig. 22). The division figure is essentially similar to the first, though smaller and with less conspicuous nucleoli. In the four-nucleate stage, the nuclei are still smaller, but they retain the characteristic appearance, with a distinct nucleolus surrounded by the clear area. A chromatin network was seen in resting nuclei only in the binucleate stage. At the end of the second division, the ascus has completed its cytoplasmic development. The inner wall of the ascus is distinct, and the ring in the tip of the outer wall is complete (Fig. 23).

The spindles of the third mitosis lie somewhat transverse to the long axis of the ascus (Fig. 24). They are long and quite slender, with still smaller nucleoli, and when complete, extend from side to side of the ascus. When the nuclei are entirely separated, they send out beaks at the point of which are located the centrosomes. From these centrosomes radiate the astral rays that delimit the spores. There is still a nucleolus present on the nucleus (Fig. 26). The spore membrane remains quite delicate until the nucleus has retreated from the wall and undergone a last mitosis (Fig. 27) which leaves the finished spore binucleate (Fig. 28).

SUMMARY

1. *Sordaria fimicola* (Rob.) Ces. and De Not. is a homothallic member of the coprophilous Sphaeriales, as indicated by cultures descended from single spores.

2. The perithecial initial is a coiled, septate, terminal hypha, which becomes invested with twining vegetative hyphae. There is no antheridium.

3. The original archicarp forms vegetative hyphae only. There arises *de novo*, a darkly staining hypha which appears to give rise to a tangle of uninucleate and binucleate cells that round off, separate, and increase in size.

4. The paired nuclei in these ascogenous cells fuse, and the cells proceed to ascus formation, sometimes with but usually without typical crozier formation.

5. The observations on the formation of the perithecial wall and neck agree with those of Woronin, Gilkinet, and Dangeard.

6. Observations on the behavior of the nuclei in the ascus, and on the formation of the ascospores agree with those of Faull.

ACKNOWLEDGMENTS

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EXPLANATION OF PLATES 28 AND 29

1. Germinating spore, × 1135.
2. Archicarp originating from several hyphae, still non-septate, ×1135.
3. Archicarp originating as a side branch of a hypha, × 1135.
4. Archicarp with septations, × 1135.
5. Archicarp surrounded with vegetative hyphae, × 1125.
6. Section through a young perithecial fundament showing homogeneous nature of the tissue, × 360.
7. Section through a little older perithecial fundament showing beginning of differentiation, with darker staining hypha in the center, × 360.
8. Portion from section of a still older perithecium. The dark cells form an ascogenous hypha, while the irregular cells are the disintegrating nourishing tissue, × 1135.
9. Portion of section of perithecium only a little younger than that in Fig. 10. Binucleate cells (c), nourishing cells (n), and a fusion nucleus (f) are to be seen, × 1135.
10. Entire section through a young perithecium, showing disintegration of the central cells, thickening of the walls, and rise of the ascogenous hyphae from the base of the perithecium, × 360.
11. Enlarged portion of Fig. 10, showing binucleate cells, nourishing cells (n), fusion nuclei (f), and a crozier (cr). The origin of the asci from the vegetative cells can be traced, × 745.
12. Section through an almost mature perithecium. The uninucleate asci are nearly full grown. The walls are complete and the neck is rapidly being formed, × 360.
13. Ascogenous hyphae from a young perithecium. The asci are just being formed. Here are shown the binucleate cells (c), nuclei fusing (f), and the fusion nucleus (a) of the young ascus.
14. Another example of the same stage.
15. Early steps in crozier formation.
16. Later stages in crozier formation. One nucleus of the primary ascus cell has presumably been cut away.
17. An irregular crozier, in which one wall has not been laid down.
18. Tip of young ascus with large fusion nucleus.
19. Metaphase of first mitosis.
20. Telophase of first mitosis.
21. Portion of a binucleate ascus, showing the nucleoli at opposite sides of the nuclei.
22. Metaphase of the second mitosis.
23. A quadrinucleate ascus. The double wall of the ascus is visible at the distal end. The thickening in the tip is the ring in the outer wall of the ascus.
24. Telophase of the last mitosis. Only two of the mitoses are visible.
25. Another example of the same stage, with astral rays apparent.
26. Spores being delimited on the astral rays from the centrosomes of the beaked nuclei.

27. The last mitosis occurring in the completely delimited spore.
28. Spores complete except for the laying down of the heavy outer wall.

Figs. 1–17 were stained in Haidenhain's iron alum haematoxylin and Orange G. Figs. 18–28 were stained in haematoxylin alone. All magnifications on Plate 29 are × 2270, others as indicated.

PLATE 28

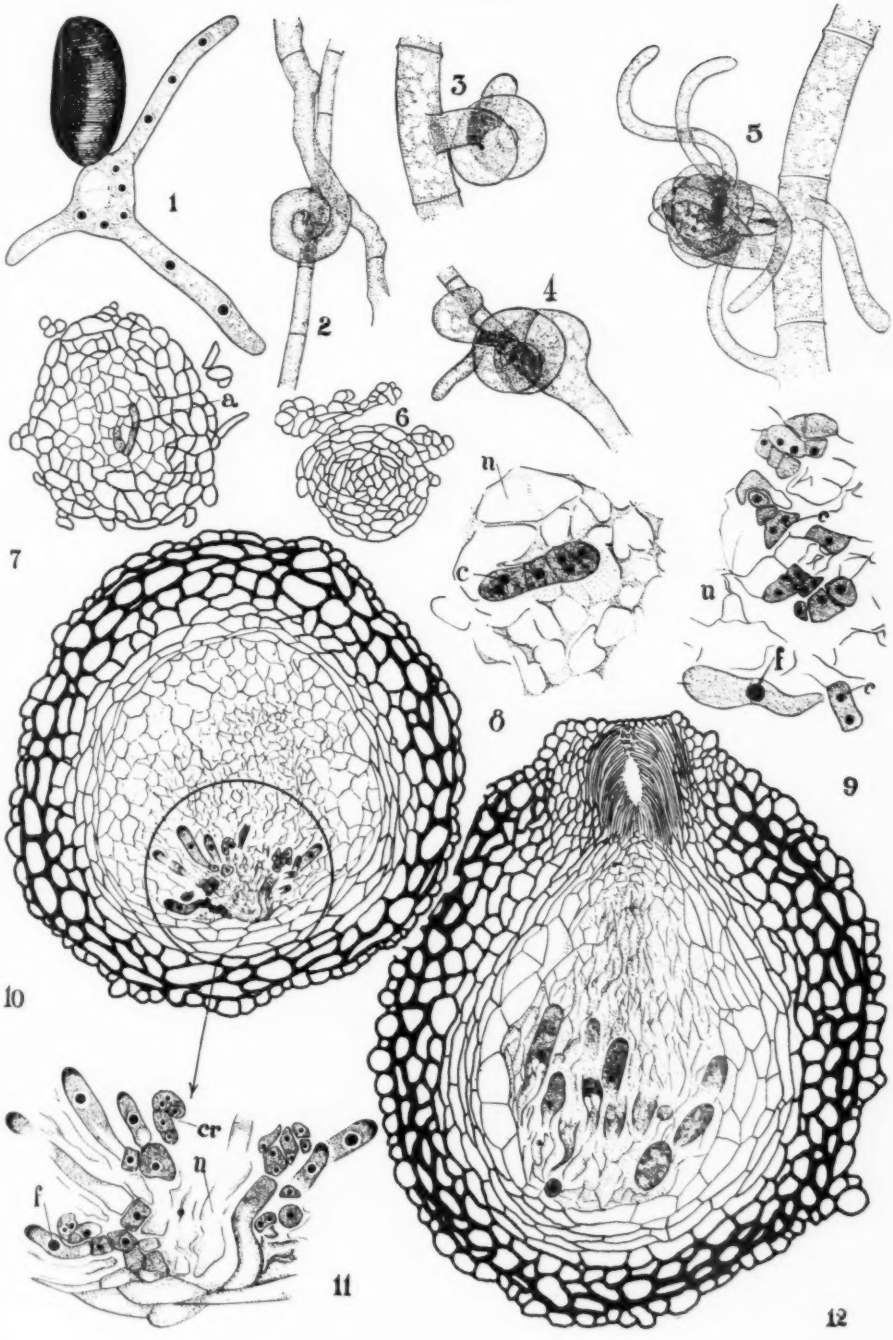
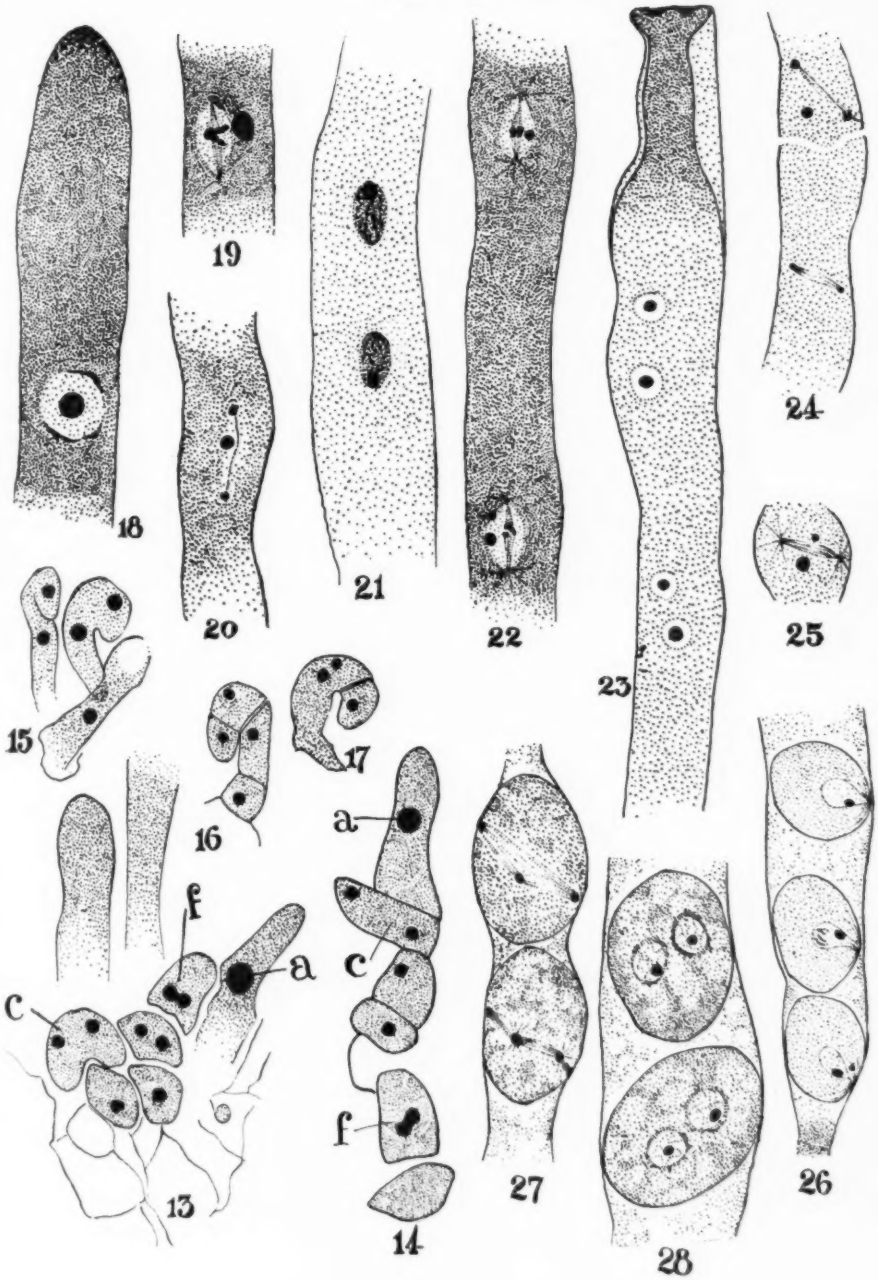


PLATE 29



OBSERVATIONS ON THE REPRODUCTION OF ANCYLISTES*

By Helen Berdan

Two species of *Ancylistes*, the type genus of the order Ancylistales, were found parasitizing species of *Closterium* from a pool in Sparrow's cow pasture, Chapel Hill, N. C., during the summer of 1937. One of these species, *A. Closterii*, was originally reported and described by Pfitzer in 1872. It has since been found by Dangeard, Sorokine, Wildeman, Constantineanu, Petersen, Schultz-Danzig, and Valkanov in Europe and Asia. The presence of this fungus in America has been noted in unpublished records of Harvey (Mississippi, 1924) and Couch (North Carolina, 1925, 1932, 1934). The second species, *A. Pfeifferi*, was discovered in Brazil and added by Beck in 1897 to the order Ancylistales established by Schröter in that same year. This species was first seen by the writer in *Closterium* species taken from a bog near London, Canada, in 1935. The presence of nine to ten blunt projections from the wall of the cell enclosing the zygote or resting-spore readily distinguishes it from *A. Closterii* in which this cell is smooth-walled.

As a result of a critical study of these two species from the Chapel Hill material, undertaken at the University of North Carolina this summer, a paper, now in press, deals with the revision of the genus *Ancylistes*. The primary basis of the revision lies in the discovery of asexual reproduction by conidia. Until now, *Ancylistes* has been separated from the other members of the order by its characteristic method of infecting by narrow tubular, external hyphae rather than by zoospores. It has now been found that these hyphae function as infection tubes only when they are entirely submerged in water. Those which emerge from water into air function as conidiophores. The conidia resemble those of *Conidiobolus* sp. (Couch) both in structure and forcible mode of discharge. Germination may produce secondary conidia or germ tubes. The germ tubes may function directly as infection tubes or as conidiophores as described by Martin for *Conidio-*

*A fuller treatment with illustrations and bibliography will appear in Mycologia in 1938.

bolus villosus. Secondary conidia may form tertiary conidia, be forcibly ejected, or germinate *in situ* by tube.

Each external hypha, which is potentially either an infection tube or a conidiophore, develops from a single internal mycelial segment. The whole protoplast of the intramatrical segment passes out through the wall of the host cell into the external hypha and flows into its growing tip by progressive stages. According to conditions, this protoplast eventually becomes concentrated in a swollen end cell of the infection hypha attached to a new host as described by Pfitzer and others, or in the conidium as observed by the writer. The content of the conidium, upon germination by tube, collects in a similar swollen infection cell. From this attached end cell of the infection hypha or the germ tube penetration of the new *Closterium* cell occurs by a fine, conical papilla. Once inside the host, the papilla elongates into a narrow tube. Through this the protoplast of the infection cell flows rapidly to form an ovoid ball in the cytoplasm of the host. Elongation into a continuous intramatrical hypha ensues. Later the hypha septates, and at maturity all the cells become either external hyphae or gametangia.

The thalli of both *A. Closterii* and *A. Pfeifferi* appear to be homothallic, conjugation being either lateral or scalariform. This disagrees with previous accounts which claim heterothallism with an appreciable difference in the diameter of the male and female filaments. Sexual reproduction appears to be mainly zygomycetous in character. The mature zygote or resting-spore, however, is seen to be retracted from the wall of the cell in which it is formed. This conforms to the view of Brefeld that sexual reproduction in *Conidiobolus* is intermediate between the true zygomycetous and oomycetous types.

The discovery of forcibly ejected conidia and lateral conjugation seems to warrant a revision of the genus *Ancylistes* and its removal from the Ancylistales to the Entomophthorales in a position near *Completoria complens* Lohde.

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